

2 out NASA CR-132783

PANORAMIC ATTITUDE SENSOR  
FOR RADIO ASTRONOMY EXPLORER -B  
APPENDICES

Final Report  
Contract NAS 5-11464

(NASA-CR-132783) PANORAMIC ATTITUDE  
SENSOR FOR RADIO ASTRONOMY EXPLORER-B,  
APPENDICES Final Report (Weston  
Instruments, Inc.) ~~123~~ p HC \$8.25

N73-27570

115

CSCL 17G G3/21

Unclass  
09779

Prepared By:  
EMR Aerospace Sciences  
EMR Division  
Weston Instruments, Inc.  
College Park, Maryland

June, 1973

Prepared For:  
National Aeronautics and Space Administration  
Goddard Space Flight Center  
Greenbelt, Maryland

## APPENDICES

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Parts List

Panoramic Attitude Sensor

for RAE-B

Revised December 8, 1971

Contract NAS 5-11464

Approval

  
\_\_\_\_\_  
EMR Quality Control

Date SEP. 30. 71

  
\_\_\_\_\_  
EMR Project Manager

Date Sep 30 1971

\_\_\_\_\_  
GSFC

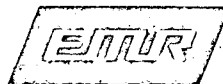
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## Parts List for Panoramic Attitude Sensor System

September 30, 1971

Listed are all electronic and electrical components for one complete system consisting of two scanner heads and one PAS electronics unit. All components listed appear in PPL 11 unless denoted by an asterisk. The PPL parts are being purchased prescreened to the specification number listed. Those parts which are not listed in PPL 11 will be screened by EMR in accordance with the EMR screening procedure number given in the column headed "specification number". All screening performed by EMR will be in accordance with the Inspection Plan for the Panoramic Attitude Sensor for RAE-B submitted to GSFC by EMR in July 1971. Outlines of the particular screening test to be applied to each non PPL semi conductor component were submitted to GSFC on September 21 along with specification sheets and requests for non standard part approval. Detailed screening test procedures will be available for review at EMR.

# PARTS LIST



## AEROSPACE SCIENCES

EMR DIVISION OF WESTON INSTRUMENTS, INC.  
A SCHLUMBERGER COMPANY

REV. DATE  
Nov. 9, 1971  
Dec. 8, 1971

PL

REV.  
A

TITLE CUMULATIVE PARTS LIST FOR  
PAS SYSTEM (MISC. ELECT. COMP.)

AUTHENTICATION

REV. NOTICE NO.

CODE IDENT. NO.  
06141

SHEET

QUAL.  
STATUS

QTY.  
REQ'D

CODE  
IDENT.  
NO.

PART NUMBER

SPECIFICATION  
NUMBER

DESCRIPTION

CUMULATIVE  
P.L.  
ITEM NO.

Qualified by  
mfg screening

3

TLB-4035

GSFC S-450-P-4A  
PB-2121-001

Relay, Latching, 4PDT, 12VDC Coils,  
Potter & Brumfield TL 17-D-12

2

Qualified by  
EMR screening

4

HP5082-4231

EMR023420-2A\*\*  
EMR023420-2B\*\*

Photo-Diode, PIN, Hewlett-Packard

Qualified by  
EMR screening

18

LS-600

EMR023420-4\*\*

Used in RAE-A  
Photo-Transistor, Texas Instruments

Qualified by  
EMR screening

12

LED SSL-35

EMR023420-5\*\*

Used in RAE-A  
Light Emitting Diode, General Electric

Qual by mfg data  
EMR screening

2

CRO-0193-75

EMR023420-6\*\*

Stepper Motor, Kearfott

Qual per PPL  
by GSFC

4

YSI 44008

GSFC-S-450-  
P-4A

Thermistor 30K $\Omega$  at 25°C for Scanner  
Temp. Monitor

Qualified by  
EMR screening

2

HSM29-20PS

EMR023420-8A\*\*  
EMR023420-8B\*\*

Connector, Hermetic, Glasseal Products, Co.

Qualified by  
mfg screening

2

75021-70 OP 090

GSFC-S-311-  
P-4

Connector, Rectangular, Sub-miniature,  
Deutsch - 100 Pin, Used in RAE-A

Qualified by  
EMR screening

4

AA40W-HP

EMR023420-10\*\*

Terminal, Hermetic, Electrical Industries, Inc.

Qual per PPL by  
GSFC

2

265001

3/0-095354

Fuse, Sub-miniature, Littlefuse, 1 amp

Qual per PPL  
by GSFC

2

YSI 44006

GSFC-S-450-  
P-4A

Thermistor, 10K $\Omega$  at 25°C, NTC

Qual per PPL  
by Mfg screening

2

1200-700

S-311-P-5/3

Filter, Low Pass EMI Supression, Erie

Qual per PPL  
by Mfr

MIL-W-16878D

Wire, Copper 26 AWG, Teflon Insulated

\*Denotes components not on PPL

\*\*Denotes EMR Screening Procedure

# PARTS LIST



## AEROSPACE SCIENCES

EMR DIVISION OF WESTON INSTRUMENTS, INC.  
A SCHLUMBERGER COMPANY

REV. DATE  
Nov. 9, 1971  
Dec. 8, 1971

PL

REV.  
A

TITLE CUMULATIVE PARTS LIST FOR  
PAS SYSTEM (MICROCIRCUIT)

AUTHENTICATION

REV. NOTICE NO.

CODE IDENT. NO.  
06141

SHEET

QUAL. STATUS	QTY. REQ'D	CODE IDENT. NO.	PART NUMBER	SPECIFICATION NUMBER	DESCRIPTION	CUMULATIVE P.L. ITEM NO.
Qual per PPL by mfg screening	18		SM54L00R1	85M03766-000	Quad 2-Input Positive Nand Gate	
"	18		SM54L04R1	85M03766-004	Hex Inverter	
"	15		SM54L10R1	85M03766-010	Triple 3-Input Positive Nand Gate	
"	5		SM54L20R1	85M03766-020	Dual 4-Input Positive Nand Gate	
"	10		SM54L30R1	85M03766-030	8-Input Positive Nand Gate	
"	10		SM54L73R1	85M03766-073	Dual J-K Master-Slave Flip-Flop	
"	8		SM54L74R1	85M03766-074	Dual D-Type Edge-Triggered Flip-Flop	
"	2		SM54L93R1	85M03766-093	4-Bit Counter	
"	9		SM54L95R1	85M03766-095	4-Bit Shift Register	
"	2		SM54L78R1	85M03766-095	Dual J-K Master-Slave Flip-Flop	
"	2		SM54L122R1	85M03766-122	Monostable Multivibrator	
* Qualified by mfg screening	6		u5T7725311	FSC Unique 38510, Class B	(EMR will perform X-ray inspection, check drift) Operational Amplifier, Fairchild Type uA725(FSC)	
"	2		LM 108H/883	MIL-M-38510-B	Operational Amplifier	

\*Denotes component not on PPL.

\*\*Denotes EMR Screening Procedure

PARTS LIST	 <b>AEROSPACE SCIENCES</b> EMR DIVISION OF WESTON INSTRUMENTS, INC. A SCHLUMBERGER COMPANY	REV. DATE Nov. 9, 1971 Dec. 8, 1971	PL	REV. A
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AEROSPACE SCIENCES

REV. DATE
Nov. 9, 1971
Dec. 8, 1971

PL

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## AUTHENTICATION

REV. NOTICE NO.

CODE IDENT. NO.  
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A SCHLUMBERGER COMPANY

REV. DATE

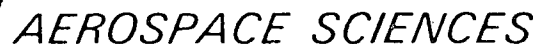
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Dec. 8, 1971

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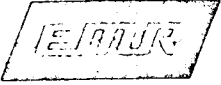


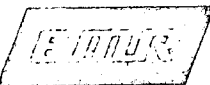
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Nov. 9, 1971

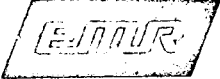
REV  
A

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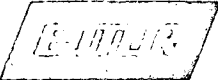


POA OR MODEL NO.				 <b>AEROSPACE SCIENCES</b>		DRAWING LIST: P.A.S.	
				EMR DIVISION OF WESTON INSTRUMENTS, INC. - A SCHLUMBERGER COMPANY		SHEET 1 OF 5	REV
						DATE: June 21, 1972	
				CONTRACT NO.: NAS 5-11464	MFG CODE 06141	APPROVED:	
				CONTRACT TITLE: Panoramic Attitude Sensor for Radio Astronomy Explorer B			
				TITLE	DWG SIZE	DRAWING NO.	REV
6341-2045	*	Cap, P.A.S. Sun Slit	B	2009	A		
	*	Spacer, P.A.S. Sun Slit	B	2010			
	*	Aperture, P.A.S.	B	2011			
	*	Spacer, Circuit Board, P.A.S.	B	2012			
	*	Sensor Mount, P.A.S.	B	2013			
	*	Bearing, Miniature, Precision	B	2014	A		
	*	Shouldered Screw, P.A.S.	B	2025			
	*	Filter Bracket, Electronics Module, P.A.S.	B	2026			
	*	Clamp, Motor, P.A.S.	B	2029			
	*	Clamp, Motor, P.A.S.	B	2030			
	*	Dome, P.A.S.	C	3030			
	*	Lens Assembly, P.A.S.	C	3031	A		
	*	Connector, Hermetically Sealed	C	3032			
	*	Feed Thru Terminal, Hermetically Sealed	C	3033			
	*	Spur Gear, Pin Hub	C	3034	A		
	*	Anti-Backlash Gear, Clamp Hub	C	3035			
	*	Stepper Motor, Size 11	C	3036	A		
	*	P.A.S. Electronics, Module Outline	C	3037			
	*	P.A.S. System Shift Register Data Formats	C	3039	A		
	*	Aperture Half, P.A.S. Sun Slit	C	3041			
	*	Aperture Half, P.A.S. Sun Slit	C	3042			
	*	Gear Shaft, P.A.S.	C	3043	A		
	*	Clamp, P.A.S.	C	3044			
	*	Printed Wiring Board, Heater Control, P.A.S.	C	3045	A		

POA OR MODEL NO.				 <b>AEROSPACE SCIENCES</b>		DRAWING LIST: P.A.S.	
				EMR DIVISION OF WESTON INSTRUMENTS, INC. - A SCHLUMBERGER COMPANY		SHEET 2 OF 5	
						REV	
6341-2045				CONTRACT NO.: NAS 5-11464		MFG CODE 06141	
				CONTRACT TITLE: Panoramic Attitude Sensor for Radio Astronomy Explorer B.		APPROVED:	
				TITLE	DWG SIZE	DRAWING NO.	REV
			*	Printed Wiring Board, Sun Slit Pre Amp, P.A.S.	C	3046	A
			*	Printed Wiring Board, Encoder Driver, P.A.S.	C	3047	
			*	Printed Wiring Board, Scanner, Pre Amp P.A.S.	C	3048	
			*	Lens Hood, P.A.S.	C	3049	
			*	Insulator, P.A.S.	C	3050	
			*	Drill Detail, Sun Slit Pre AMP, P.A.S.	C	3051	
			*	Drill Detail, Scanner Pre Amp, P.A.S.	C	3052	A
			*	Drill Detail, Heater Control, P.A.S.	C	3053	A
			*	Drill Detail, Encoder Driver, P.A.S.	C	3054	
			*	Insulator, Printed Wiring Board, P.A.S.	C	3064	
			*	Encoder Assembly, P.A.S.	D	4037	C
			*	Gear Plate, P.A.S.	D	4038	B
			*	Gear Plate, P.A.S.	D	4039	C
			*	P.A.S. Heater Control Schematic	D	4040	
			*	Encoder & Telescope Assy., P.A.S.	D	4045	A
			*	Printed Wiring Board Stepper Drive, P.A.S.	D	4047	
			*	Drill Detail, Stepper Drive, P.A.S.	D	4048	A
			*	Printed Wiring, Assembly Encoder Driver, P.A.S.	D	4049	A
			*	Printed Wiring, Assembly Scanner Pre Amp, P.A.S.	D	4050	B
			*	Printed Wiring Board, Scanner Select & Pulse Generator, BD#2, P.A.S.	D	4051	B

POA OR MODEL NO.				 <b>AEROSPACE SCIENCES</b>		DRAWING LIST: P.A.S.	
						SHEET 3 OF 5	REV
				EMR DIVISION OF WESTON INSTRUMENTS, INC. - A SCHLUMBERGER COMPANY		DATE: June 21, 1972	
				CONTRACT NO.: NAS 5-11464	MFG CODE 06141	APPROVED:	
CONTRACT TITLE: Panoramic Attitude Sensor for Radio Astronomy Explorer B							
				TITLE	DWG SIZE	DRAWING NO.	REV
				* Printed Wiring Assembly, Sun Slit Pre Amp, P.A.S.	D	4052	A
				* Printed Wiring Assembly, Heater Control P.A.S.	D	4053	A
				* Drill Detail, Scanner Select & Pulse Generator, Board #2, P.A.S.	D	4056	
				* Front Panel, Electronics Module, P.A.S.	D	4064	
				* Electronic Module Assembly, P.A.S.	D	4071	
				* P.A.S. Sensor Pre Amp Schematic	E	5013	D
				* Scanner Cabling Diagram, P.A.S.	E	5014	D
				* Stepper Motor & Encoder Driver Circuit	E	5015	C
				* Electronic Module P.A.S. Schematic Diagram	E	5016	L
				* Case, Upper Half, P.A.S.	E	5019	B
				* Printed Wiring Board, Mode Control, P.A.S.	E	5023	A
				* Printed Wiring Board, AOS/LOS Counter and Shift Register, P.A.S.	E	5024	A
				* Printed Wiring Board, AOS/LOS Strobe Generator, P.A.S.	E	5025	A
				* Printed Wiring Board, Input Gates, Encoder and Boom Blanking, BD#6, P.A.S.	E	5026	A
				* Printed Wiring Board Command Relay & Input Conditioning	E	5027	C
				* Printed Wiring Assembly, Stepper Drive, P.A.S.	E	5028	B

POA OR MODEL NO.				DRAWING LIST: P.A.S.		
				SHEET 4 OF 5	REV	
				DATE: June 21, 1972		
				APPROVED:		
6341-2045				CONTRACT NO.: NAS 5-11464		
				MFG CODE 06141		
CONTRACT TITLE: Panoramic Attitude Sensor for Radio Astronomy Explorer B						
TITLE				DWG SIZE	DRAWING NO.	REV
* Drill Detail, AOS/LOS Counter and Shift Register, Board #5, P.A.S.				E	5029	
* Drill Detail, Mode Control, Board #3, P.A.S.				E	5030	
* Drill Detail, AOS/LOS Strobe Generator, Board #4, P.A.S.				E	5031	
* Drill Detail, Command Relays and Input Conditioning, Board #1, P.A.S.				E	5032	A
* Drill Detail, Input Gates, Encoder Zero & Boom Blanking, Board #6, P.A.S.				E	5033	
* Printed Wiring Assembly, Command Relays & Input Conditioning, Bd #1, P.A.S.				E	5038	E
* Printed Wiring Assembly, Input Gates, Encoder Zero & Boom Blanking, Board #6, P.A.S.				E	5040	B
* Printed Wiring Assembly, Scanner Select & Pulse Generator, Board #2, P.A.S.				E	5042	C
* Printed Wiring Assembly, AOS/LOS Strobe Generator, Board #4, P.A.S.				E	5043	A
* Printed Wiring Assembly, Mode Control, Board #3, P.A.S.				E	5046	B
* Printed Wiring Assembly, AOS/LOS, Counter and Shift Register, Bd #5, P.A.S.				E	5048	
* Interwiring Diagram, Electronics Module, P.A.S.				E	5049	A

POA OR MODEL NO.				 <b>AEROSPACE SCIENCES</b>		DRAWING LIST: P.A.S.	
6341-2045				EMR DIVISION OF WESTON INSTRUMENTS, INC. - A SCHLUMBERGER COMPANY		SHEET 5 OF 5	REV
				DATE: June 21, 1972		APPROVED:	
				CONTRACT NO.: NAS 5-11464		MFG CODE 06141	
				CONTRACT TITLE: Panoramic Attitude Sensor for Radio Astronomy Explorer B			
				TITLE	DWG SIZE	DRAWING NO.	REV
				* Gear Train Assembly, P.A.S.	E	5051	A
				* Panoramic Attitude Sensor Assembly	E	5052	A
				* Case, Lower Half, P.A.S.	J	7024	
				* Case Assy, Lower Half P.A.S.	C	3078	
				* Case Assy, Upper Half P.A.S.	C	3079	
				* Sun Shield Lower P.A.S.	C	3083	A
				* Sun Shield Upper P.A.S.	C	3084	A
				* Spacer, Notched P.A.S.	B	2047	

PROCEDURE NO.  
6341-2045-1

ENVIRONMENTAL  
QUALIFICATION TEST PROCEDURE  
PANORAMIC ATTITUDE SENSOR  
FOR RAE-B

CONTRACT NAS 5-11464

APPROVAL: <u>R. Thomson</u>	DATE <u>10-25-72</u>
EMR-ENGINEERING	
<u>K. Hughes</u>	DATE <u>5-18-72</u>
EMR-QUALITY CONTROL	
<u>A. H. Harrison</u>	DATE <u>10-25-72</u>
NASA-GSFC	

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## 1.0 SCOPE

This procedure is intended to cover all environmental testing on a prototype subsystem panoramic attitude sensor for the Radio Astronomy Explorer "B" spacecraft.

## 2.0 APPLICABLE DOCUMENTS

The following documents apply to the extent specified herein:

- 2.1 The Contract NAS 5-11464
- 2.2 NASA-GSFC S-320-RAE-3, Environmental Test Specification
- 2.3 Inspection plan for PAS, Contract NAS5-11464
- 2.4 GSFC S-724-P7

## 3.0 TEST CONDITION

The following conditions shall apply unless otherwise specified:

Temperature in Test Areas:	$25 \pm 5^{\circ}\text{C}$
Pressure:	Normal Atmospheric
Humidity:	maximum 70%
Level of Gravity:	$G \pm 10\%$
Power Spectral Density:	$\text{PSD} \pm 3\text{db}$
Frequency:	$f \pm 5\%$ or 1 Hz whichever is greater

#### 4.0 LIST OF EQUIPMENT

The following instruments or their equivalents shall be used:

VEECO MS-0 Leak Detector  
Calidyne Mod. A-174 Shaker, 1500 lb. vector  
B & K Mod. 1039 Vibration Control Console  
MB Model T495 Equalizer Analyzer  
BU Model 4333 Accelerometer  
Fixturing as applicable  
PAS Test Set  
Temperature Test Chamber, Delta Designs

#### 5.0 ENVIRONMENTAL TESTS

##### 5.1 Confirmation of Operation

Subject scanner head to the operational tests of Section 6.2

##### 5.2 Sinusoidal Vibration

Scanner head only to be tested. Secure the article under test rigidly to the vibration table and subject to the following vibrational stresses:

5.2.1 Z Axis	Prototype Levels	Flight System Levels (including flight spares)
5 - 11 Hz	0.48" DA	0.32" DA
11 - 17 Hz	3 G	2.0 g
17 - 23 Hz	7.5 G	5.0 g
23 - 45 Hz	3.0 G	2.0 g
45 - 90 Hz	0.03" DA	0.02" DA
90 - 115 Hz	12 G	8.0 g
115 - 1000 Hz	6 G	4.0 g
1000 - 2000 Hz	15 G	10.0 g
	at 2 octaves/min.	at 4 octaves/min.

5.2.2	X and Y Axes	Prototype Levels	Flight System Levels (including flight spares)
	5 - 7.5 Hz	0.80" DA	0.52" DA
	7.5 - 13 Hz	2.3 G	1.5 g
	13 - 200 Hz	3.0 G	2.0 g
	200 - 2000 Hz	5.0 G	3.3 g
		at 2 octaves/min.	at 4 octaves/min.

5.2.3 Inspect article for damage as a result of this vibration

5.3 Random Vibration -- Scanner head only to be tested

5.3.1 Secure article rigidly to vibration table and subject to the following stresses:

5.3.2 Random vibration in each of 3 mutually perpendicular axes with a power spectral density at the frequency ranges as follows: (Flight System)

20 - 300 Hz .0013 to 0.02 g<sup>2</sup>/Hz  
at + 3db/octave

300 - 2000 Hz 0.02 g<sup>2</sup>/Hz

For an overall PSD of 6.1 g rms at 2 minutes each per axis

5.3.3 Inspect article for damage as a result of this vibration.

5.4 Repeat scanner operating test of Section 6.2.

5.5 Helium Leak Test -- Scanner head only to be tested

5.5.1 Connect exhaust tubing to leak detector and start pump down until detector pressure is below 20 microns of mercury (Ready Light on).

5.5.2 Flush exterior of housing with helium flowing at a rate of 10 - 30 cc/minutes specifically follow seams in housing.

5.5.3 Observe helium leak rate on meter to be set at 10<sup>-6</sup> STD cc/sec range

5.5.4 Accept if leak rate is less than  $1.0 \times 10^{-6}$  standard cc/sec.

## 5.6 Thermal Test

Complete PAS system. Place PAS system in temperature chamber and connect to PAS test set. Install thermocouple to monitor scanner head temperature.

5.6.1 Cool scanner to  $-20^{\circ}\text{C} \pm 5^{\circ}\text{C}$  and hold for one hour. Perform all operational tests of Section 6.

5.6.2 Heat scanner to  $+60^{\circ}\text{C} \pm 5^{\circ}\text{C}$  and hold for one hour. Perform all operational tests of Section 6.

5.6.3 Cool scanner to  $-20^{\circ}\text{C} \pm 5^{\circ}\text{C}$  and hold for 1 hour. Perform all operational tests of Section 6.

5.6.4 Heat scanner to  $+60^{\circ}\text{C} \pm 5^{\circ}\text{C}$  and hold for 1 hour. Perform all operational tests of Section 6.

## 6.0 OPERATING TESTS

### 6.1 System Test

6.1.1 Measure voltage and current each input

Logic Power	$5\text{V} \pm .1\text{V}$	$170 \pm 60$ ma scanning/ $140 \pm 60$ ma standby
Preamp Power	$12\text{V} \pm .2\text{V}$	40 ma max
Motor Power	$18\text{V} \pm .2\text{V}$	$110 \pm 40$ ma scanning/ $--10$ ma max standby
Relay Power	$12\text{V} \pm .2\text{V}$	5 ma max

## 6.2 Scanner Head Tests

6.2.1 Verify 512 step scanner operation with stop on zero. Interrupt motor power, verify operation of-off zero light. Verify return to normal operation in two cycles.

### 6.2.2 Scanner step-encoder output correlation test

Operate scanner in planar mode to stop on zero. Switch mode select to spherical mode, position 2. Verify correlation between motor step count (upper register, binary) and encoder output display (lower register, Gray code) for the first 32 steps of rotation. The encoder output display lags by slightly more than one step behind the actual encoder position.

<u>Decimal</u>	<u>Binary</u>	<u>Gray</u>
1	1	1
2	01	11
3	11	01
4	001	011
5	101	111
6	011	101
7	111	1
8	0001	0011
9	1001	1011
10	0101	1111
11	1101	0111
12	0011	0101
13	1011	1101
14	0111	1001
15	1111	0001
16	00001	00011
17	10001	10011
18	01001	11011
19	11001	01011
20	00101	01111

<u>Decimal</u>	<u>Binary</u>	<u>Gray</u>
21	10101	11111
22	01101	10111
23	11101	00111
24	00011	00101
25	10011	10101
26	01011	11101
27	11011	01101
28	00111	01001
29	10111	11001
30	01111	10001
31	11111	00001
32	000001	000011

### 6.3 Electronics Tests

#### 6.3.1 Planar Mode, Normal Target (AOS precedes LOS)

Set AOS switch bank to  $2^6$

Set LOS switch bank to  $2^4$

Verify light bank readout

AOS display  $2^6$  000000100

LOS display  $2^4 + 2^6$  000010100

#### 6.3.2 Planar Mode, Inverted Target (LOS precedes AOS)

Set AOS switch bank to  $2^6$

Set LOS switch bank to  $2^4$

Verify light bank readout - Anomaly light on

AOS display  $2^4 + 2^6$  000010100

LOS display  $2^6$  000000100

### 6.3.3 Spherical Mode, Normal Target

Set AOS count to  $2^5$

Set LOS count to  $2^3$

Verify readout	<u>Readout if using PAS Sun Pulse</u>	or	<u>Readout if using Test Set Sun Pulse</u>
AOS display	1111110000		0000001000
LOS display	1000100XX		1000100XX

### 6.3.4 Spherical Mode, Inverted Target, Test set normal period

Set AOS count to  $2^5$

Set LOS count to  $2^3$

Verify readout and Anomaly flag on

	<u>Readout if using PAS Sun Pulse</u>	or	<u>Readout if using Test Set Sun Pulse</u>
AOS display	1111000000		111100000
LOS display	0000001XX		1000001XX

# POWER SPECTRAL DENSITY

JOB \_\_\_\_\_

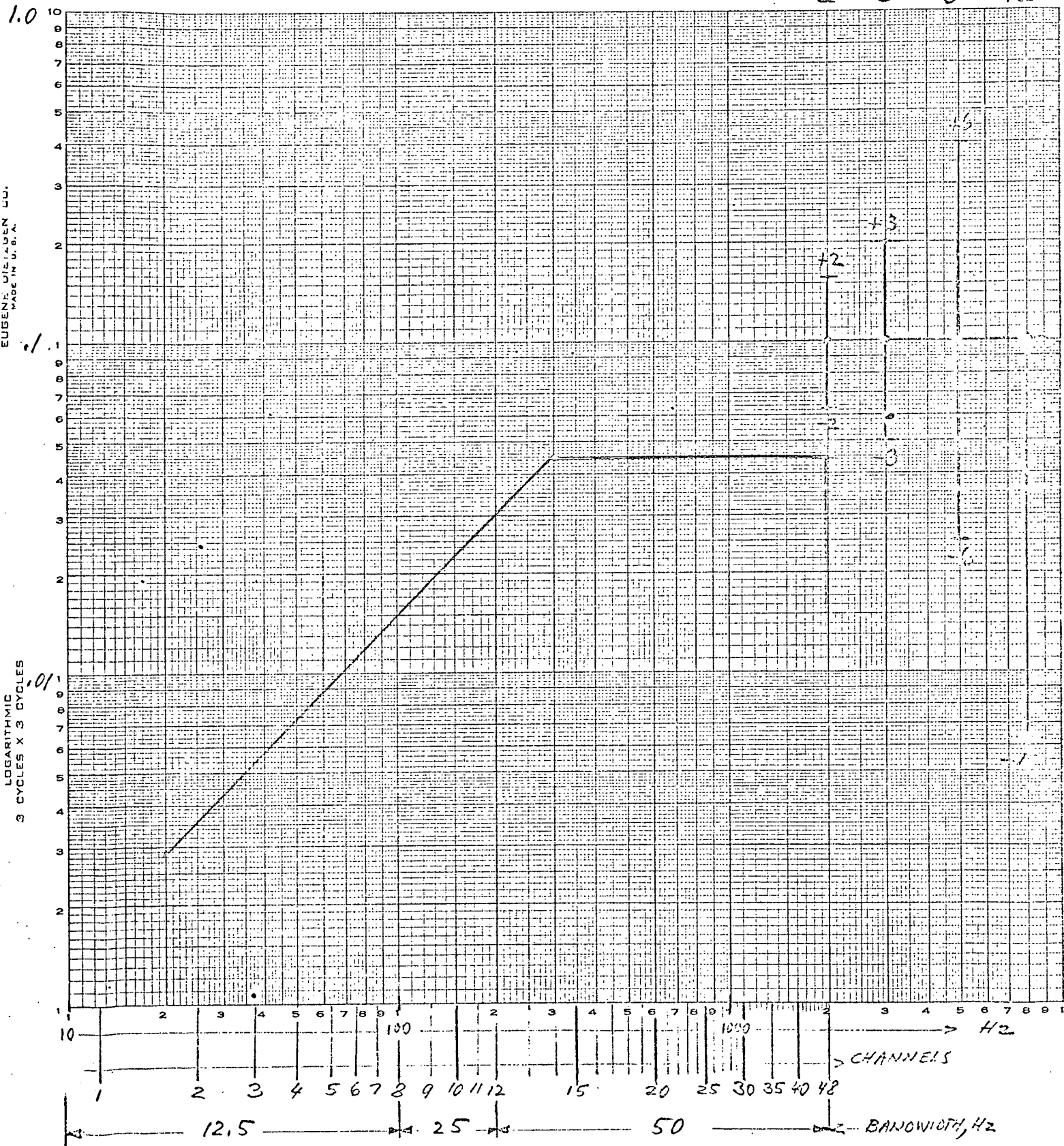
$g^2/Hz$

dB SCALE

















1.0

EUGENE DESIGN CO.  
MADE IN U.S.A.

LOGARITHMIC  
3 CYCLES X 3 CYCLES



ENVIRONMENTAL TEST REPORTARTICLE SCANNER HEAD S/N 02 (Prototype)

3.0	Verified Test Conditions		( ) within limits
5.0	ENVIRONMENTAL TEST		
5.1	<u>Scanner operation acceptable</u>	 23 MAY 72	
5.2	<u>Sinusoidal Vibration</u>		(X) check
	Article under test secured		(X) check
5.2.1	Vibration at Z axis complete		(X) check
5.2.2	Vibration at X axis complete		(X) check
	Vibration at Y axis complete		(X) check
5.2.3	Inspection for damage & acceptable		(X) check
5.3	<u>Random Vibration</u>		
5.3.1	Article under test secured		(X) check
5.3.2	Random vibration at X axis		(X) check
	Random vibration at Y axis		(X) check
	Random vibration at Z axis		(X) check
5.3.3	Inspection for damage, acceptable		(X) check
5.4	<u>Leak Test complete, acceptable</u>		(X) check
5.5	<u>Scanner operation acceptable</u>		(X) check
5.6	<u>Thermal Test</u>		
	-20°C Operation acceptable		(X) check
	+60°C Operation acceptable		(X) check
	-20°C Operation acceptable		(X) check
	+60°C Operation acceptable		(X) check

This is to certify that the tests specified in 2045-1 procedure have been conducted on the article identified above. Date 6-5-72

Test Supervisor

Reb Thomson

Quality Control

SSS Lafford 5 JUN 72

EXCEPT 5.5 &amp; 5.6

REF. LETTER TO A DAVIDSON 25 MAY 72

TEST PROCEDURE NO.

OPERATING TEST REPORT

ARTICLE SCANNER HEAD S/N 02

6.1 System Test

6.1.1 Voltage and current within limits N/A ( ) check

6.2 Scanner Head Tests

6.2.1 Stepping operation acceptable (✓) check

6.2.2 Scanner-Encoder correlation acceptable (✓) check

6.3 Electronics Tests

6.3.1 P.M., normal target response acceptable N/A ( ) check

6.3.2 P.M., inverted target response acceptable N/A ( ) check

6.3.3 S.M., normal target response acceptable N/A ( ) check



















6.3.4 S.M., inverted target response acceptable N/A ( ) check

Test Article operation acceptable (✓) check

TEST PROCEDURE NO.

ENVIRONMENTAL TEST REPORT

ARTICLE PAS Scanner S/N 8

- |       |                                       |   |
|-------|---------------------------------------|---|
| 3.0   | Verified Test Conditions              |  (✓) within limit. |
| 5.0   | ENVIRONMENTAL TEST                    |   |
| 5.1   | <u>Scanner operation acceptable</u>   |   |
| 5.2   | <u>Sinusoidal Vibration</u>           |  (✓) check         |
|       | Article under test secured            |  (✓) check         |
| 5.2.1 | Vibration at Z axis complete          |  (✓) check         |
| 5.2.2 | Vibration at X axis complete          |  (✓) check         |
|       | Vibration at Y axis complete          |  (✓) check        |
| 5.2.3 | Inspection for damage & acceptable    |  (✓) check       |
| 5.3   | <u>Random Vibration</u>               |   |
| 5.3.1 | Article under test secured            |  (✓) check       |
| 5.3.2 | Random vibration at X axis            |  (✓) check       |
|       | Random vibration at Y axis            |  (✓) check       |
|       | Random vibration at Z axis            |  (✓) check       |
| 5.3.3 | Inspection for damage, acceptable     |  (✓) check       |
| 5.4   | <u>Scanner operation acceptable</u>   |  (✓) check       |
| 5.5   | <u>Leak Test complete, acceptable</u> |  ( ) check       |
| 5.6   | <u>Thermal Test</u>                   |   |
|       | -20°C Operation acceptable            |  (✓) check       |
|       | +60°C Operation acceptable            |  (✓) check       |
|       | -20°C Operation acceptable            |  (✓) check       |
|       | +60°C Operation acceptable            |  (✓) check       |

This is to certify that the tests specified in procedure have been conducted on the article identified above. Date 29 Nov 72

Test Supervisor

Reb Thomsen













Quality Control

ST. Staffort



## TEST PROCEDURE NO.

ENVIRONMENTAL TEST REPORTARTICLE PAS Scanner S/N 9

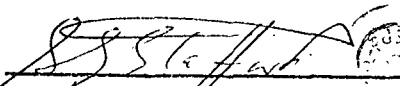

3.0	Verified Test Conditions		(✓) within limit
5.0	ENVIRONMENTAL TEST		
5.1	<u>Scanner operation acceptable</u>		
5.2	<u>Sinusoidal Vibration</u>		(✓) check
	Article under test secured		(✓) check
5.2.1	Vibration at Z axis complete		(✓) check
5.2.2	Vibration at X axis complete		(✓) check
	Vibration at Y axis complete		(✓) check
5.2.3	Inspection for damage & acceptable		(✓) check
5.3	<u>Random Vibration</u>		
5.3.1	Article under test secured		(✓) check
5.3.2	Random vibration at X axis		(✓) check
	Random vibration at Y axis		(✓) check
	Random vibration at Z axis		(✓) check
5.3.3	Inspection for damage, acceptable		(✓) check
5.4	<u>Scanner operation acceptable</u>		(✓) check
5.5	<u>Leak Test complete, acceptable</u>		( ) check
5.6	<u>Thermal Test</u>		
	-20°C      Operation acceptable		(✓) check
	+60°C      Operation acceptable		(✓) check
	-20°C      Operation acceptable		(✓) check
	+60°C      Operation acceptable		(✓) check

This is to certify that the tests specified in      procedure have been  
 conducted on the article identified above.      Date 29 Nov 72

Test Supervisor

Reb Thomsen

Quality Control

## TEST PROCEDURE NO.

# OPERATING TEST REPORT

ARTICLE PAS Flight System S/N Scanners SN 8 & 9  
Thermal Test Room Temperature Check Oct 27

## 6.1 System Test

Scanner 8 OK ✓  
Scanner 9 did check

### 6.1.1 Voltage and current within limits

## 6.2 Scanner Head Tests

Scanner OK ✓  
~~Scanner OK~~ check  
 Scanner OK ✓  
~~Scanner OK~~ check

### 6.2.1 Stepping operation acceptable

### 6.2.2 Scanner-Encoder correlation acceptable

### 6.3 Electronics Tests

6.3.1 P.M., normal target response acceptable

6.3.2 P.M., inverted target response acceptable

6.3.3 S.M., normal target response acceptable

6.3.4 S.M., inverted target response acceptable

Test Article operation acceptable

(✓) check

Scanner # 8  
5.V

5. V 5003

171 me / 140 me

12V                      12.04V

8.9 ma. Preamp + Relay

18V                      18.07V

III ma / 0,6 ma

Scanner # 9

5,02 ✓

172 ma / 140 ma

12.04 ✓

9.1 mV Preamp + Relay

18.06 ✓

 $113 \text{ me} / 0.6 \text{ me}$

# TEST PROCEDURE NO.

## OPERATING TEST REPORT

ARTICLE VAS Flight System S/N Scanners 8 & 9, Electronics

Thermal Test, First Cold Cycle -20°C at 2:15 PM OCT 27  
Begin Test 3:15 PM

### 6.1 System Test

6.1.1 Voltage and current within limits

Scanner 8 OK  
Scanner 9 OK (✓) check

### 6.2 Scanner Head Tests

6.2.1 Stepping operation acceptable

Scanner 8 OK  
Scanner 9 OK ( ) check

6.2.2 Scanner-Encoder correlation acceptable

Scanner 8 OK  
Scanner 9 OK ( ) check

### 6.3 Electronics Tests

6.3.1 P.M., normal target response acceptable

(✓) check

6.3.2 P.M., inverted target response acceptable

(✓) check

6.3.3 S.M., normal target response acceptable

(✓) check

6.3.4 S.M., inverted target response acceptable

(✓) check

Test Article operation acceptable

(✓) check

Scanner 8, -20°C

5.00 V	178 ma / 144 ma
12.06 V	9.8 ma
18.14 V	148 ma / 1 ma
Heater 14.16 V	139.8 ma

Scanner 9 -

5.00 V	178 / 145 ma
12.05 V	10.6 ma
18.1	144.6 ma / 0.8 ma
Heater 14.16 V	139.6 ma

OPERATING TEST REPORT

ARTICLE PAS Flight System S/N Scanners 8 & 9  
Thermal Test, First Hot Cycle at 60°C Oct 27 1972

6.1 System Test

6.1.1 Voltage and current within limits

Scanner 9 OK ✓  
 Scanner 8 OK (✓) check

6.2 Scanner Head Tests

6.2.1 Stepping operation acceptable

Scanner # 8 OK ✓  
 Scanner # 9 OK (✓) check

6.2.2 Scanner-Encoder correlation acceptable

Scanner # 9 (✓) check  
 Scanner # 8 OK ✓

6.3 Electronics Tests

6.3.1 P.M., normal target response acceptable

\_\_\_\_\_ (✓) check

6.3.2 P.M., inverted target response acceptable

\_\_\_\_\_ (✓) check


6.3.3 S.M., normal target response acceptable

\_\_\_\_\_ (✓) check

6.3.4 S.M., inverted target response acceptable

\_\_\_\_\_ (✓) check

Test Article operation acceptable

 (✓) check



 Scanner # 9

5.00 V      166 / 136 ma  
 12.04      9.7 ma  
 18.08      89.7 / 0.7 ma  
 Heater 14.15 V      11.9 ma

 Scanner # 8

5.02      166 / 136 ma  
 12.03 V      8.2 ma  
 18.1 V      91.8 / 0.7  
 Heater 14.16      12.0 ma

OPERATING TEST REPORTARTICLE PAS Flight Sys. SIN Scanner 8 & 9  
25° Pre-test check before test Oct 28, 1972

6.1	<u>5.6.3</u> <u>System Test</u>	#8 OK #9 OK ( ) check
6.1.1	Voltage and current within limits	
6.2	<u>Scanner Head Tests</u>	#8 OK #9 OK ( ) check
6.2.1	Stepping operation acceptable	#8 OK #9 OK ( ) check
6.2.2	Scanner-Encoder correlation acceptable	#8 OK #9 OK ( ) check
6.3	<u>Electronics Tests</u>	
6.3.1	P.M., normal target response acceptable	OK ( ) check
6.3.2	P.M., inverted target response acceptable	OK ( ) check
6.3.3	S.M., normal target response acceptable	OK ( ) check
6.3.4	S.M., inverted target response acceptable	OK ( ) check

Test Article operation acceptable

OK ( ) check

Test conducted 10-28-72-1030 AM

J. McKay

Scanner #8

5.00V	171 ma / 139 ma
12.04V	8.7 ma
18.1V	114 ma / 0.9 ma
14.18V	12.4 ma

Scanner #9

5.02V	170 ma / 139 ma
12.04V	10.0 ma
18.07V	112 ma / 0.7 ma
14.2V	12.2 ma

# TEST PROCEDURE NO.

## OPERATING TEST REPORT

ARTICLE PAS Flight System S/N Scanners SN 8 and 9  
Thermal test second cold cycle -20.0°C OCT 28 1972

- |       |   |                            |
|-------|---|----------------------------|
| 6.1   | <u>System Test</u>                        | Scanner 9 OK ✓             |
| 6.1.1 | Voltage and current within limits         | <u>Scanner 8</u> (✓) check |
| 6.2   | <u>Scanner Head Tests</u>                 | Scanner 9 OK ✓             |
| 6.2.1 | Stepping operation acceptable             | <u>Scanner 8</u> (✓) check |
| 6.2.2 | Scanner-Encoder correlation acceptable    | <u>Scanner 9</u> (✓) check |
|       |   | <u>Scanner 8</u> (✓) check |
| 6.3   | <u>Electronics Tests</u>                  |                            |
| 6.3.1 | P.M., normal target response acceptable   | <u>OK</u> (✓) check        |
| 6.3.2 | P.M., inverted target response acceptable | <u>OK</u> (✓) check        |
| 6.3.3 | S.M., normal target response acceptable   | <u>OK</u> (✓) check        |
| 6.3.4 | S.M., inverted target response acceptable | <u>OK</u> (✓) check        |

Test Article operation acceptable

OK (✓) check

Completed 12:15 PM Oct 28 R. Thomas

### Scanner # 9

5.03 V 180/146 ma

11.99 V 11.3 ma

18.0 147/1.8 ma

Heater 14.24 V 141.2 ma

### Scanner # 8

5.03 V 180/146 ma

12.00 V 10.5 ma

18.17.9 V 149/1.7 ma

Heater 14.2 V 140.9 ma

# TEST PROCEDURE NO.

## OPERATING TEST REPORT

ARTICLE PAS Flight System S/N Scanners SN 8 and 9  
Thermal Test Second Hot Cycle 60°C Oct 28 1972

- |       |   |                         |
|-------|---|-------------------------|
| 6.1   | <u>System Test</u>                        | Scanners 8 OK ✓         |
| 6.1.1 | Voltage and current within limits         | Scanner 9 ✓ check       |
| 6.2   | <u>Scanner Head Tests</u>                 | Scanner 9 OK ✓          |
| 6.2.1 | Stepping operation acceptable             | *Scanner 8 mal. (check) |
| 6.2.2 | Scanner-Encoder correlation acceptable    | Scanner 9 OK ✓ check    |
| 6.3   | <u>Electronics Tests</u>                  | *Scanner 8 malfunction* |
| 6.3.1 | P.M., normal target response acceptable   | _____ (✓) check         |
| 6.3.2 | P.M., inverted target response acceptable | _____ (✓) check         |
| 6.3.3 | S.M., normal target response acceptable   | _____ (✓) check         |
| 6.3.4 | S.M., inverted target response acceptable | _____ (✓) check         |

Test Article operation acceptable

Not Acceptable PAS ( ) check

\*MRD 07100 CLOSED 29 NOV 72 (SSS)

With system at 60°C the errors occurred in the L.S.B of the encoder readout. when these errors occurred, they always consisted of a high reading on a low immediately preceding a high eg sequence should be → 0011001100110011

Scanner 9 actual output at 60°C → 011011100110111  
 ↑ typical error

5.08V 168/139 ma  
 11.94V 10.9 ma  
 18.10V 86.8/1.6 ma  
 Heater 14.2V 12.9 ma

Scanner 8

5.08V 167/138 ma  
 11.95V 8.8 ma  
 18.10V 88.6/1.2 ma  
 Heater 14.2V 12.5 ma

Customer: EMR-Aerospace Sciences (College Park)  
Customer Purchase Order \_\_\_\_\_ Date Test Completed: 10-30-72

Quantity	Model Number	Serial Number	Test Requirement
2	PAS Flight Scanner	8 & 9	Z Axis (TEST I) 5-11 Hz 0.32" D.A. 11-17 Hz 2.0 G 17-23 Hz 5.0 G 23-45 Hz 2.0 G 45-90 Hz 0.02" D.A. 90-115 Hz 8.0 G 115-1000 Hz 4.0 G 1000-2000 Hz 10 G

Notes:		X & Y Axis (TEST 2)	Random 3 Axis (TEST 3)
5-7.5 Hz	0.52" D.A.		20 - 300 Hz .0013 to
7.5-13 Hz	1.5 G		0.02g <sup>2</sup> /Hz at +3db/octave
13-200 Hz	2.0G		300-2000 Hz 0.02 <sup>2</sup> /Hz
200-2000 Hz	3.3 G		PSD of 6.1g rms at 2 min/axis.

ALL THREE AXIS 4 oct/min.

Make	Model	Serial Number	Calibration Due
Calidyne	Shaker A 174	15D94	12-16-72
3&K	Control Console	123830	12-16-72
3&K	Accelerometer 4333	271957	12-16-72

This is to certify that the above listed units have been subjected to the specified stresses and that the environmental test equipment was under calibration traceable to NBS.

Date October 30, 1972

FOR Anthony Marciano  
Mgr. Reliability & Quality Control

A 88

TEST PROCEDURE NO.

OPERATING TEST REPORT

Oct 30 1972

ARTICLE PAS Flight Scanner S/N 8 and 9

Room Temperature Check after vibration using breadboard electronics

6.1 System Test

6.1.1 Voltage and current within limits

Scanner 8 OK ✓

Scanner 9 (✓) check

6.2 Scanner Head Tests

6.2.1 Stepping operation acceptable

Scanner 8 OK ✓

Scanner 9 ( ) check

6.2.2 Scanner-Encoder correlation acceptable

Scanner 8 (✓) check

Scanner 9 OK ✓

6.3 Electronics Tests

6.3.1 P.M., normal target response acceptable

NA ( ) check

6.3.2 P.M., inverted target response acceptable

NA ( ) check

6.3.3 S.M., normal target response acceptable

NA ( ) check

6.3.4 S.M., inverted target response acceptable

NA ( ) check

Test Article operation acceptable



(✓) check



Scanner # 8

5.007 V 185.8 / 152 ma

11.98 V 14.5 ma

18.05 V 140 / 4.2 ma (using breadboard electronics)

14.2 V 18.9 ma



Scanner # 9

5.01 V 185 / 150 ma

12.00 V 15.3 ma

18.05 V 139 / 3.9 ma using breadboard electronics

14.2 V 6.3 ma



TEST PROCEDURE NO.

OPERATING TEST REPORT

Oct 30 1972 7:30 PM

ARTICLE PAS Flight System

Flight Electronics  
S/N Scanners 8 and 9

Test at 60°C (System at 60°C from 6:30 PM)

6.1 System Test

6.1.1 Voltage and current within limits

\_\_\_\_\_ ( ) check

6.2 Scanner Head Tests

6.2.1 Stepping operation acceptable

Scanner 8 OK ✓  
Scanner 9 OK ✓

6.2.2 Scanner-Encoder correlation acceptable

Scanner 8 OK ✓  
Scanner 9 OK ✓

6.3 Electronics Tests

Measurement completed 8:15 PM, Scanners at 60°C

6.3.1 P.M., normal target response acceptable

OK ( ) check

6.3.2 P.M., inverted target response acceptable

OK ( ) check

6.3.3 S.M., normal target response acceptable

OK ( ) check

6.3.4 S.M., inverted target response acceptable

OK ( ) check

Test Article operation acceptable

\_\_\_\_\_ ( ) check

Scanner 8

5.02 V 177/140 ma  
11.96 V 14.1 ma  
18.06 V 124 / ~~12~~ ma  
14.2 ~~12.2~~ ma 18.1 ma

Recheck Scanner 8 7:55 PM

5.03 V 172/137  
11.96 9.3 ma  
18.06 120 / ~~12~~ 1.2 ma  
14.2 V .7

Scanner 9

5.02 V 182/141  
11.95 V 19.8 ma  
18.1 V 129 / ~~12~~ ma  
14.2 V ~~23~~ ma ?

Scanner 9

18.1 V 119 / 1.2 ma

OPERATING TEST REPORT

ARTICLE PAS FLIGHT SYSTEM S/N FLIGHT ELECTRONICS  
SCANNER # 8  
SCANNER # 7  
 TEST 5.6.4 (REPEAT) AT +60°C. (Soak time 90 minutes)

- |       |   |                    |
|-------|---|--------------------|
| 6.1   | <u>System Test</u>                        | SCAN # 8           |
| 6.1.1 | Voltage and current within limits         | SCAN # 9 (X) check |
| 6.2   | <u>Scanner Head Tests</u>                 | SCAN # 8           |
| 6.2.1 | Stepping operation acceptable             | SCAN # 9 (Y) check |
| 6.2.2 | Scanner-Encoder correlation acceptable    | SCAN # 8           |
|       |   | SCAN # 7 (X) check |
| 6.3   | <u>Electronics Tests</u>                  |                    |
| 6.3.1 | P.M., normal target response acceptable   | _____ (X) check    |
| 6.3.2 | P.M., inverted target response acceptable | _____ (Y) check    |
| 6.3.3 | S.M., normal target response acceptable   | _____ (X) check    |
| 6.3.4 | S.M., inverted target response acceptable | _____ (X) check    |

Test Article operation acceptable 10-31-72 9:25 AM J M. Kay (X) check



SCANNER # 8 VOLTS/CURRENT

5.06 - 173/138

12.09 - 9.4

18.06 - 119/1.1

14.2 - 12.6



SCANNER # 9 VOLTS/CURRENT

5.02 - 172/137

12.08 - 11.4

18.01 - 119/1.5

14.2 - 12.9



PROCEDURE NO.  
6341-0245-2

CALIBRATION PROCEDURE  
  
PANORAMIC ATTITUDE SENSOR  
  
FOR RAE-B

CONTRACT NAS 5-11464

APPROVAL: R. Thuman DATE 5-26-72

EMR-ENGINEERING

S. S. Taylor DATE 5/26/72

EMR-QUALITY CONTROL

A. E. Hanson DATE 5-26-72

NASA-GSFC

## 1.0 SCOPE

This procedure covers all measurements and tests required to perform the calibration of the Panoramic Attitude Sensor system as defined in Section 9.1.5 of the contract statement of work (GSFC S-724-P7). This is a test of the complete system, including both scanner head and electronics.

## 2.0 APPLICABLE DOCUMENTS

The following documents apply to the extent specified herein.

2.1 The Contract NAS 5-11464

2.2 NASA-GSFC S-320-RAE-3 Environmental Test Specification

2.3 Inspection Plan for PAS Contract NAS 5-11464

2.4 GSFC S-724-P7

## 3.0 TEST CONDITIONS

Temperature in test area	$25^{\circ}\text{C} \pm 5^{\circ}\text{C}$
Pressure	Normal atmosphere
Humidity	Maximum 70%

## 4.0 LIST OF EQUIPMENT

PAS test set

Rotary table with slip rings

## 5.0 CALIBRATION

### 5.1 Spherical Mode

#### 5.1.1 Azimuth Angles (X-Y plane)

Mount scanner head on rotary table with Z axis parallel to axis of rotation of table. Set up light sources at distance of not less than 1 meter from scanner: 1) a high intensity light source subtending not more than 1/2 degree to activate the sun slit and 2) a target light source extended in the X-Y plane with sharply defined boundaries to activate the scanner. Measure accurately ( $\pm 1^\circ$ ) the angular width of the target source and the angular spacing between the sun slit source and the target source as seen by the scanner.

Rotate the scanner head successively at speeds of 50 RPM  $\pm 5\%$ , 12 RPM  $\pm 5\%$  and 4 RPM  $\pm 5\%$  and read out the AOS and LOS count in each case. Block the target source and measure the AOS count corresponding to a full revolution of the scanner. Verify registry between the AOS and LOS counts and the measured range geometry to within the following tolerances.

<u>RPM</u>	<u>AOS</u>	<u>LOS</u>	<u>AOS to LOS</u>	<u>Spin Rate</u>
50	$\pm .85^\circ$	$\pm .85^\circ$	$\pm 1.3^\circ$	$\pm .1\%$
12	$\pm .85^\circ$	$\pm .85^\circ$	$\pm 1.3^\circ$	$\pm .1\%$
4	$\pm 1.0^\circ$	$\pm 1.0^\circ$	$\pm 1.5^\circ$	$\pm .1\%$

#### 5.1.2 Elevation Angles (Z axis reference)

Mount the extended light source parallel to the scanner Z axis. Measure angular width of target and angular elevation of target above XY plane of scanner. Advance scanner in spherical mode until target is first acquired. Determine elevation angle corresponding to AOS from step count. Continue to advance scanner in spherical mode until target is lost. Again determine elevation angle from step count. Verify registry between step count

and range geometry to within the following tolerances.

AOS	$\pm .45^{\circ}$
LOS	$\pm .45^{\circ}$
AOS to LOS	$\pm .90^{\circ}$

## 5.2 Planar Mode (Z axis reference)

The scanner head will be mounted on a non-rotating fixture, and an extended light source will be placed in the X-Y plane at a distance of not less than 1 meter from the scanner. The angular width of the target subtended at the scanner and the angular displacement of the target from the scanner zero position will be determined. The scanner will be operated in planar mode at 100 steps/second and AOS and LOS readouts determined. The angles corresponding to these readouts will be determined and compared with the measured range geometry to verify accuracy within the following tolerances.

AOS	$\pm .45^{\circ}$
LOS	$\pm .45^{\circ}$
AOS to LOS	$\pm .90^{\circ}$

CALIBRATION REPORT

5.1 Spherical Mode Prototype PAS System

5.1.1 Azimuth Angles (X-Y plane)

Range angles

Sun source to start of target

Sun source to end of target

Start of target to end of target

*These measurements  
conducted separately.  
See supplementary sheets.*

PAS readout	50 RPM		12 RPM		4 RPM	
	Count	Angle	Count	Angle	Count	Angle
AOS						
LOS	<i>not applicable in spherical mode</i>					
AOS to LOS						
AOS no target						

5.1.2 Spherical Mode Elevation Angles

Range geometry angles

Start of target elevation angle N.A.

End of target elevation angle N.A.

Start of target to end of target angle 14.8°

PAS readout	Count	Angle
AOS #1	<i>NO reference for AOS due to misalignment of encoder disc.</i>	
LOS #2		
AOS to LOS		
	$20 \times \frac{360}{512}$	$= 14.1$

5.1.3 Verified spherical mode operation with tolerances



( )

*EXCEL 110.0  
11/15/12*

## 5.2 Planar Mode Elevation Angles

Range geometry angles      Zero reference at  $34.75^\circ$   
 Start of target elevation angle       $100.41^\circ - 34.75^\circ = 65.66^\circ$   
 End of target elevation angle       $130.26 - 34.75 = 95.51$   
 Start of target to end of target angle       $130.26 - 100.41 = 29.85^\circ$

PAS readout	Count	Angle
AOS	$94 \times \frac{360}{372} =$	$66.1^\circ$ $.44^\circ$
LOS	136	$95.5^\circ$ $.01^\circ$
AOS to LOS	42	$29.5^\circ$ $.35^\circ$

Verified planar mode operation within tolerances



( )

## 5.3 Solar Response Width of Scanner

Determine the solar response width of the scanner in degrees by slowly scanning across a simulated sun source.      Simulated sun approx  $1/10$  S.C.  $\times 1/2^\circ$

Solar response width 28.1 degrees total width.

## 5.4 System calibration procedure completed

System calibration acceptable



( )



with exceptions as follows

- 5.1.1 LOS measurement does not exist in spherical mode.
- 5.1.2 LOS measurement does not exist in spherical mode.
- AOS measurement not feasible with encoder malfunction. will be repeated.

CALIBRATION REPORT

5.1 Spherical Mode

5.1.1 Azimuth Angles (X-Y plane)

Spin Period Measurement Accuracy Test  
(Clock frequency derived from PAS test set)

Nominal 50 RPM

Nominal 800 Hz Clock

True spin period 1.1998 sec True RPM 50.0

AOS count for full revolution 971

True clock frequency 809.4 Hz

Spin period determined by PAS  $\frac{971}{809.4} = 1.996 \text{ sec}$

Fractional error  $\frac{.0002}{1.2} = .00017 \text{ } (.017\%)$



Nominal 12 RPM

Nominal 200 Hz Clock

True spin period 4.8024 sec True RPM 12.5

AOS count for full revolution 972

True clock frequency 202.35 Hz

Spin period determined by PAS  $\frac{972}{202.35} = 4.8047 \text{ sec}$

Fractional error  $\frac{.0023}{4.8} = .00048 = .048\%$



Nominal 4 RPM

Nominal 50 Hz Clock

True spin period 13.240 sec True RPM 4.5

AOS count for full revolution 670

True clock frequency 50.58 Hz

Spin period determined by PAS  $\frac{670}{50.58} = 13.2463 \text{ sec}$

Fractional error  $\frac{.006}{13} = .00043 = .043\%$



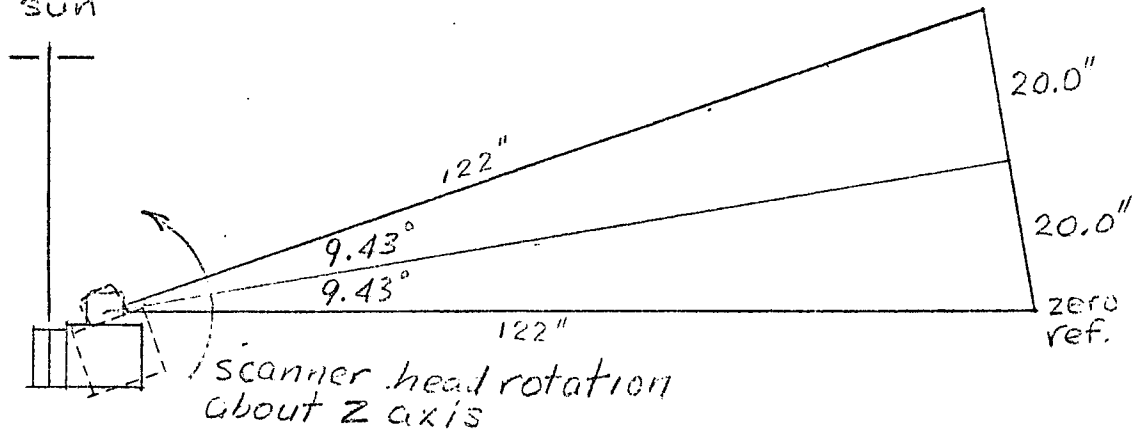
CALIBRATION REPORT

5.1 Spherical Mode

5.1.1 Azimuth Angles (X-Y plane)

Target AOS and AOS to LOS Measurement Accuracy Test

simulated  
sun



Range angles

Scanner direction at sun pulse - zero ref.  $0.00^\circ$   
 Scanner direction at start of target -  $\text{Arc sin } \frac{20.0}{122} = 9.43^\circ$   
 Scanner direction at end of target  $2 (\text{Arc sin } \frac{20.0}{122}) = 18.86^\circ$

Angle Determinations by PAS System

50 RPM Nominal

800 Hz Clock

True spin period  $1.1854 \text{ sec}$  True RPM  $50.6$

True clock  $809.2 \text{ Hz}$

AOS count  $25$

AOS angle  $\frac{25 \times 360}{809.2 \times 1.185} = 9.382^\circ$

AOS error  $9.43 - 9.38 = 0.05^\circ$



$$\begin{aligned}
 \text{AOS to LOS count} & 28-1 = 27 \\
 \text{AOS to LOS angle} & \frac{27 \times 360}{809.2 \times 1.185} = 10.133^\circ \\
 \text{AOS to LOS error} & 10.133^\circ - 9.43^\circ = 0.70^\circ
 \end{aligned}$$

12 RPM Nominal

200 Hz Clock



$$\begin{aligned}
 \text{True spin period} & 4.8187 \text{ sec} \quad \text{True RPM} \quad 12.4 \\
 \text{True clock} & 202.3 \text{ Hz} \\
 \text{AOS count} & 25 \\
 \text{AOS angle} & \frac{25 \times 360}{202.3 \times 4.8187} = 9.232^\circ \\
 \text{AOS error} & 9.43^\circ - 9.23^\circ = 0.20^\circ \\
 \text{AOS to LOS count} & 29-1 = 28 \\
 \text{AOS to LOS angle} & \frac{28 \times 360}{202.3 \times 4.8187} = 10.340^\circ \\
 \text{AOS to LOS error} & 10.34 - 9.43 = 0.91^\circ
 \end{aligned}$$

4 RPM Nominal

50 Hz Clock



$$\begin{aligned}
 \text{True spin period} & 12.296 \text{ sec} \quad \text{True RPM} \quad 48.8 \\
 \text{True clock} & 50.58 \text{ Hz} \\
 \text{AOS count} & 17 \\
 \text{AOS angle} & \frac{17 \times 360}{50.58 \times 12.296} = 9.840^\circ \\
 \text{AOS error} & 9.84 - 9.43 = 0.41^\circ \\
 \text{AOS to LOS count} & 19-1 = 18 \\
 \text{AOS to LOS angle} & \frac{18 \times 360}{50.58 \times 12.296} = 10.419^\circ \\
 \text{AOS to LOS error} & 10.419^\circ - 9.43^\circ = 0.99^\circ
 \end{aligned}$$

CALIBRATION REPORT November 8, 1972

Scanner No. 8, Flight Electronics

5.1 Spherical Mode

5.1.1 Azimuth Angles (X-Y plane)

Spin Period Measurement Accuracy Test

(Clock frequency derived from PAS test set)

Nominal 50 RPM Scanner No. 8	Nominal 800 Hz Clock
True spin period 1.14840 sec	True RPM 52.3
AOS count for full revolution 929	
True clock frequency 809.38 Hz	
Spin period determined by PAS 1.16385 sec	1.14779 sec
Fractional error .115 %	.05%

Nominal 12 RPM	Nominal 200 Hz Clock
True spin period 4.73991 sec	True RPM 12.6
AOS count for full revolution 959	
True clock frequency 202.30 Hz	
Spin period determined by PAS 4.74048 sec	
Fractional error .014%	

Nominal 4 RPM	Nominal 50 Hz Clock 50.58
True spin period 13.588 sec	True RPM 4.42
AOS count for full revolution 687	
True clock frequency 50.58 Hz	
Spin period determined by PAS	$\frac{687}{50.58} = 13.582 \text{ sec}$
Fractional error	

$$\frac{.006}{13} = \frac{.6\%}{13} = .046\%$$

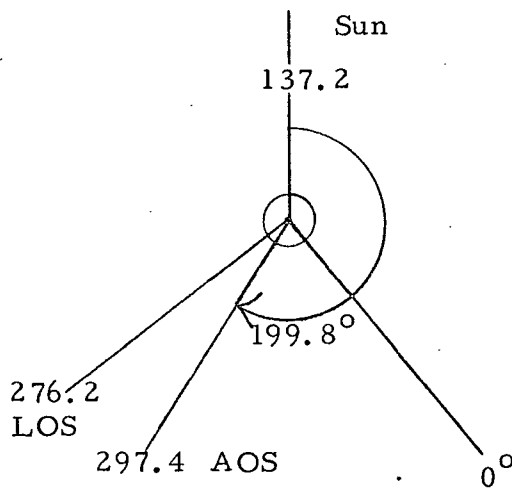
CALIBRATION REPORT - November 8, 1972

Scanner No. 8, Flight Electronics

5.1 Spherical Mode

5.1.1 Azimuth Angles (X-Y plane) Scanner No. 8

Target AOS and AOS to LOS Measurement Accuracy Test



Range angles

Scanner direction at sun pulse - zero ref.  $137.2^{\circ}$

Scanner direction at start of target .....  $137.2 + 360 - 297.4 = 199.8^{\circ}$

Scanner direction at end of target .....  $137.2 + 360 - 276.2 = 121.0^{\circ}$

AOS to LOS Angle  $297.4 - 276.2 = 21.2^{\circ}$

Angle Determinations by PAS System

50 RPM Nominal

800 Hz Clock

True spin period 1.12291 sec True RPM 53.4

True clock 809.38 Hz

AOS count  $256 + 128 + 64 - 32 + 16 + 8 + 2 = 506$

AOS angle  $\frac{506 \times 360}{1.12291 \times 809.38} = 200.43^{\circ}$

AOS error  
.63°

$$\begin{aligned}\text{AOS to LOS count} & 32 + 16 + 4 = 52 \\ \text{AOS to LOS angle} & \frac{(52-1)(360)}{1.12291 \times 809.38} = 20.20^\circ \\ \text{AOS to LOS error} & 21.20 - 20.20 = 1.0^\circ\end{aligned}$$

12 RPM Nominal Scanner #8                      200 Hz Clock

$$\begin{aligned}\text{True spin period} & 4.72605 \text{ sec} & \text{True RPM} & 12.7 \\ \text{True clock} & 202.30 \text{ Hz} \\ \text{AOS count} & 512 + 16 + 1 = 529 \\ \text{AOS angle} & \frac{529 \times 360}{4.726 \times 202.30} = 199.19^\circ \\ \text{AOS error} & 199.8^\circ - 199.19^\circ = 0.61^\circ \\ \text{AOS to LOS count} & 32 + 16 + 8 + 3 = 59 \\ \text{AOS to LOS angle} & 21.839^\circ \\ \text{AOS to LOS error} & 21.839 - 21.20^\circ = 0.64^\circ\end{aligned}$$

4 RPM Nominal Scanner 8                      50 Hz Clock

$$\begin{aligned}\text{True spin period} & 13.497 \text{ sec.} & \text{True RPM} & 4.45 \\ \text{True clock} & 50.58 \text{ Hz} \\ \text{AOS count} & 256 + 64 + 32 + 16 + 8 + 1 = 377 & \text{Repeat Measure} & 373 \\ \text{AOS angle} & \frac{377 \times 360}{13.497 \times 50.58} = 198.805^\circ & & 199.37^\circ \\ \text{AOS error} & 199.8 - 198.8 = 1.0^\circ \text{ error} & & 199.8 - 199.37 = 0.43^\circ \text{ error} \\ \text{AOS to LOS count} & 32 + 8 + 2 = 42 & & 42 \\ \text{AOS to LOS angle} & \frac{(42-1)(360)}{13.497 \times 50.58} = 21.62^\circ & & \frac{(42-1)(360)}{13.316 \times 50.58} = 21.91^\circ \\ \text{AOS to LOS error} & 21.62^\circ - 21.20^\circ = 0.42^\circ & & 21.91^\circ - 21.20^\circ = 0.71^\circ\end{aligned}$$

5.1.2 Spherical Mode Elevation Angles Scanner No. 8

Range geometry angles

$$\begin{aligned}\text{Start of target elevation angle} & -10.212^\circ + 360^\circ = 349.788^\circ \\ \text{End of target elevation angle} & +10.212^\circ \\ \text{Start of target to end of target angle} & 20.414^\circ\end{aligned}$$

<u>PAS readout</u>	<u>Count</u>	<u>Angle</u>	<u>Error</u>
AOS 110100001	498	350.156	0.368
LOS 000100001	15	10.547	0.355
AOS to LOS	29	20.391	0.024

5.1.3 Verified spherical mode operation within tolerances \_\_\_\_\_ (✓)

5.2 Planar Mode Elevation Angles

Start of target elevation angle  $230.6^{\circ}$

End of target elevation angle  $247.9^{\circ}$

Start of target to end of target angle  $17.3^{\circ}$

<u>PAS readout</u>	<u>Count</u>	<u>Angle</u>	
AOS	328	$230.625^{\circ}$	error $0.025^{\circ}$
LOS	353	$248.203^{\circ}$	error $0.303^{\circ}$
AOS to LOS	25	$17.578^{\circ}$	$17.578 - 17.3^{\circ} = 0.278^{\circ}$ error

Verified planar mode operation within tolerances \_\_\_\_\_ (✓)

5.3 Solar Response Width of Scanner Scanner No. 8 November 8, 1972

Determine the solar response width of scanner in degrees by slowly scanning across a simulated sun source.

$$137.3 - 136.75 = 0.55^{\circ}$$

Solar response width 0.55 degrees total width.

Sun at  $45^{\circ}$  above XY plane - Solar response  $130.6^{\circ} - 129.7^{\circ} = 0.90^{\circ}$  width

5.4 System calibration procedure completed

System calibration acceptable \_\_\_\_\_ (✓)

CALIBRATION REPORT

Nov 8 1972

5.1 Spherical Mode Scanner No 8, Flight Electronics

5.1.1 Azimuth Angles (X-Y plane)

Spin Period Measurement Accuracy Test

(Clock frequency derived from PAS test set)

Nominal 50 RPM Scanner No 8 Nominal 800 Hz Clock



True spin period  $1.16519$  True RPM

AOS count for full revolution  $512 + 256 + 128 + 32 + 8 + 4 + 2 = 942$   
 $512 + 256 + 128 + 32 + 1 = 929$

True clock frequency 809.38

Spin period determined by PAS  $1.16385$   $1.14779$

Fractional error  $\frac{.00134}{1.16} = .00115 = .115\%$   $.0006 = .0005 = .05\%$

Probably measured spin period for different revolution

Nominal 12 RPM Nominal 200 Hz Clock



True spin period 4.73991 True RPM

AOS count for full revolution  $512 + 256 + 128 + 32 + 8 + 4 + 2 + 1 = 959$

True clock frequency 202.30

Spin period determined by PAS 4.74048

Fractional error  $\frac{.00057}{4} = .014\%$

Nominal 4 RPM

Nominal 50 Hz Clock 50.58



True spin period 13.588 True RPM

AOS count for full revolution  $512 + 128 + 32 + 8 + 4 + 2 + 1 = 687$

True clock frequency 50.58

Spin period determined by PAS  $\frac{687}{50.58} = 13.582$

Fractional error

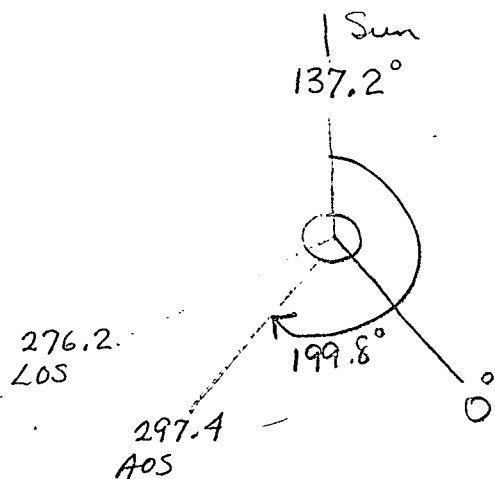
$$\frac{.006}{13} = \frac{.6}{13} \% = .046\%$$

CALIBRATION REPORT

5.1 Spherical Mode

5.1.1 Azimuth Angles (X-Y plane) *Scanner No 8*

Target AOS and AOS to LOS Measurement Accuracy Test



Range angles

Scanner direction at sun pulse - zero ref.  $137.2^\circ$   
 Scanner direction at start of target ~~137.2~~  $137.2 + 360 - 297.4 = 199.8^\circ$   
 Scanner direction at end of target 2 (Arc sin  $137.2 + 360 - 276.2 = 121.0^\circ$   
 AOS to LOS angle  $297.4 - 276.2 = 21.2^\circ$

Angle Determinations by PAS System

50 RPM Nominal

800 Hz Clock

True spin period  $1.12291$  True RPM

True clock  $809.38 \text{ Hz}$

AOS count  $256 + 128 + 64 + 32 + 16 + 8 + 2 = 506$

AOS angle  $\frac{506 \times 360}{1.12291 \times 809.38} = 200.43$

AOS error  
 $.63^\circ$

$$\text{AOS to LOS count } 32 + 16 + 4 = 52$$

$$\text{AOS to LOS angle } \frac{(52-1)(360)}{1.12291 \times 809.38} = 20.20^\circ$$

$$\text{AOS to LOS error } 21.20 - 20.20 = 1.0^\circ$$

12 RPM Nominal Scanner #8 200 Hz Clock



True spin period 4.72605 True RPM

True clock 202.30

$$\text{AOS count } 512 + 16 + 1 = 529$$

$$\text{AOS angle } \frac{529 \times 360}{4.726 \times 202.30} = 199.19$$

$$\text{AOS error } 199.8^\circ - 199.19^\circ = 0.61^\circ \text{ error}$$

$$\text{AOS to LOS count } 32 + 16 + 8 + 3 = 59$$

$$\text{AOS to LOS angle } = 21.839$$

$$\text{AOS to LOS error } 21.839 - 21.20^\circ = 0.64^\circ \text{ error}$$

4 RPM Nominal Scanner 8 50 Hz Clock 50.58 Hz actual



True spin period 13.497 sec

True RPM

Repeat measure

True clock

- 373

$$\text{AOS count } 256 + 64 + 32 + 16 + 8 + 1 = 377$$

$$\text{AOS angle } \frac{377 \times 360}{13.497 \times 50.58} = 198.805$$

$$\text{* AOS error } 199.8 - 198.8 = 1.0^\circ \text{ error}$$

$$\text{AOS to LOS count } 32 + 5 + 2 = 42$$

$$\text{AOS to LOS angle } \frac{(42-1)(360)}{13.497 \times 50.58} = 21.62^\circ$$

$$\text{AOS to LOS error } 21.62^\circ - 21.20^\circ = 0.42^\circ \text{ error}$$

$$199.8 - 199.37 = 0.43^\circ \text{ error}$$

42

$$21.91^\circ$$

\* Error beyond specified 0.85°, excess believed to be due to variation of angular speed of rotary table ACCEPTABLE used to test scanner. measurement repeated twice more, 960 11-8-72 measured well within specified tolerance. R.T.

$$\text{AOS error } 199.8^\circ - 199.31^\circ = 0.49^\circ$$

# 5.1.2 Spherical Mode Elevation Angles

Scanner NO 0

Nov 72

## Range geometry angles

Start of target elevation angle  $-10.212^{\circ} + 360^{\circ} = 349.788^{\circ}$

End of target elevation angle  $+10.212^{\circ}$

Start of target to end of target angle  $20.414^{\circ}$

PAS readout

Count

Angle

error

AOS 100100001

498

350.156

0.368

ge of target LOS 000100001

15

10.547 ✓

0.355

11-7-72

et completely 000110000

(16+1)

~~11.25~~

0.024

Out AOS to LOS

29 → 20.89

~~29 30~~ → 21.09

## 5.1.3 Verified spherical mode operation with tolerances

\*

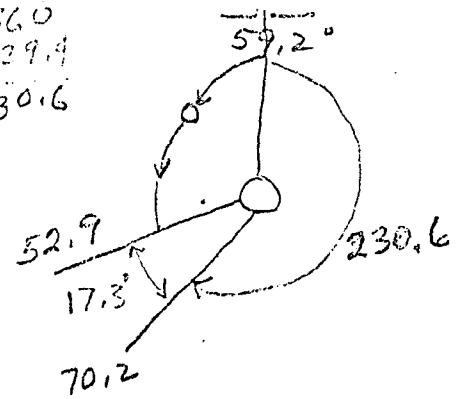
()

\* para 5.1.2 above discussed with act Division 10 Nov 72  
and the condition above is acceptable R SHAAR-555

Scanner No 8

Nov 5 1972

360  
- 129.4  
230.6



## 5.2 Planar Mode Elevation Angles

Range geometry angles

Start of target elevation angle 230.6°

End of target elevation angle 247.9°

Start of target to end of target angle

PAS readout

Count

Angle

AOS

328

230.625

error 0.025°

LOS

353

248.203

error 0.303°

AOS to LOS

25

17.578°

17.578 - 17.3° = 0.278° error

Verified planar mode operation within tolerances

(V)

## 5.3 Solar Response Width of Scanner

Scanner No 8

Nov 8 1972

Determine the solar response width of the scanner in degrees by slowly scanning across a simulated sun source. 137.3 - 136.75 = 0.55°

Solar response width \_\_\_\_\_ degrees total width.

Sun at 45° above XY plane Solar response 130.6° - 129.7° = 0.90° width

## 5.4 System calibration procedure completed

System calibration acceptable

\*

(V)

\*Acceptable with changes as noted in procedure (SS)

CALIBRATION REPORT

5.1 Spherical Mode

5.1.1 Azimuth Angles (X-Y plane)

Range angles

Sun source to start of target

Sun source to end of target

Start of target to end of target

PAS readout	50 RPM		12 RPM		4 RPM	
	Count	Angle	Count	Angle	Count	Angle
AOS						
LOS						
AOS to LOS						
AOS no target						

5.1.2 Spherical Mode Elevation Angles

Scanner No 8 Nov 9 1972

Range geometry angles

Start of target elevation angle  $-10.212^{\circ} + 360^{\circ} = 349.788^{\circ}$

End of target elevation angle  $+10.212^{\circ}$

Start of target to end of target angle  $20.414^{\circ}$

PAS readout	Count	Angle
AOS 100100001	498	350.156
LOS 000100001	15	10.547
AOS to LOS 000110000	16	11.25
	29 →	20.89
	30 →	21.09

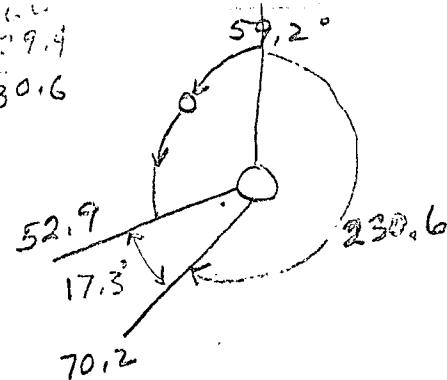
1-8  
11-9-72



5.1.3 Verified spherical mode operation with tolerances

\_\_\_\_\_ ( )

230.6  
- 179.4  
230.6



## 5.2 Planar Mode Elevation Angles

Range geometry angles

Start of target elevation angle 230.6°

End of target elevation angle 247.9

Start of target to end of target angle

PAS readout	Count	Angle	
AOS	328	230.625	error 0.025°
LOS	353	248.203	error 0.303°
AOS to LOS	25	17.578°	

$$17.578 - 17.3 = 0.278^\circ \text{ error}$$

Verified planar mode operation within tolerances \_\_\_\_\_ ( )

## 5.3 Solar Response Width of Scanner

Determine the solar response width of the scanner in degrees by slowly scanning across a simulated sun source.

Solar response width \_\_\_\_\_ degrees total width.

## 5.4 System calibration procedure completed

System calibration acceptable \_\_\_\_\_ ( )

5.2 Planar Mode Elevation Angles

Range geometry angles

Start of target elevation angle

End of target elevation angle

Start of target to end of target angle

PAS readout                      Count                      Angle

AOS

LOS

AOS to LOS

Verified planar mode operation within tolerances \_\_\_\_\_ ( )

5.3 Solar Response Width of Scanner *Scanner No 8* *Nov 8 1972*

Determine the solar response width of the scanner in degrees by slowly scanning across a simulated sun source.  $137.3 - 136.75 = 0.55^\circ$

Solar response width \_\_\_\_\_ degrees total width.

*Sun at 45° above XY plane Solar response  $130.6^\circ - 129.7^\circ = 0.90^\circ$  width*

5.4 System calibration procedure completed

System calibration acceptable \_\_\_\_\_ ( )

CALIBRATION REPORT    November 8, 1972  
Scanner No. 9, Flight Electronics

5.1    Spherical Mode

5.1.1    Azimuth Angles (X-Y plane)

Spin Period Measurement Accuracy Test  
(Clock frequency derived from PAS test set)

Nominal 50 RPM	Nominal 800 Hz Clock
True spin period 1.1636 sec.	True RPM 51.6
AOS count for full revolution 942	
True clock frequency.....	809.28 Hz      809.38 Hz
Spin period determined by PAS..	1.16399 sec    1.16385 sec
Fractional error.....	.04%      .022%

Nominal 12 RPM	Nominal 200 Hz Clock
True spin period 4.74356 sec	True RPM 12.7
AOS count for full revolution 960	
True clock frequency 202.3 Hz	
Spin period determined by PAS 4.7454 sec	
Fractional error .04%	

Nominal 4 RPM	Nominal 50 Hz Clock
True spin period 14.8423 sec	True RPM 4.04
AOS count for full revolution 750	
True clock frequency 50.58	
Spin period determined by PAS 14.828	
Fractional error 14.842 - 14.828 = .014	

$$\frac{.014}{14.8} = .095\%$$

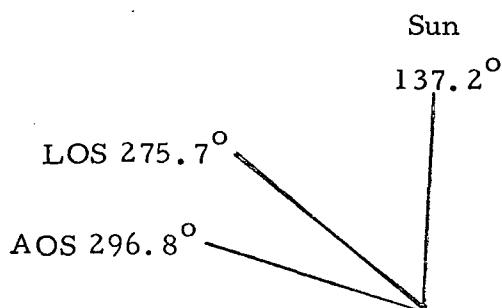
CALIBRATION REPORT - Nov. 8, 1972

Scanner No. 9, Flight Electronics

5.1 Spherical Mode

5.1.1 Azimuth Angles (X-Y plane)

Target AOS and AOS to LOS Measurement Accuracy Test



Range angles

Scanner direction at sun pulse - zero ref.  $137.2^\circ$

Scanner direction at start of target  $137.2 + (360 - 296.8) = 200.4^\circ$

Scanner direction at end of target  $137.2 + (360 - 275.7) = 221.5^\circ$

AOS to LOS Angle  $296.8 - 275.7 = 21.1^\circ$

Angle Determinations by PAS System

50 RPM Nominal Scanner No. 9 800 Hz Clock

True spin period 1.23829 True RPM

True clock 809.38

AOS count  $32 + 8 + 4 + 1 + 512 = 557$

AOS angle  $\frac{557 \times 360}{1.23829 \times 809.38} = 200.07^\circ$

AOS error  
 $200.4 - 200.07 = 0.33^\circ$

$$\begin{aligned} \text{AOS to LOS count} & 32 + 16 + 8 + 4 + 1 = 61 \\ \text{AOS to LOS angle} & \frac{(61-1)(360)}{1.23829 \times 809.38} = 21.55^\circ \\ \text{AOS to LOS error} & 21.55 - 21.1 = 0.45^\circ \text{ error} \end{aligned}$$

12 RPM Nominal Scanner No. 9      200 Hz Clock

True spin period 4.72437 sec.      True RPM 12.7

True clock 202.3 Hz

AOS count  $512 + 16 + 3 = 531$

$$(200.4^\circ) \text{ AOS angle } \frac{531 \times 360}{4.72437 \times 202.3} = 200.01^\circ$$

AOS error  $0.4^\circ$

AOS to LOS count  $32 + 16 + 8 + 2 = 58$

$$(21.1^\circ) \text{ AOS to LOS angle } \frac{(58-1)(360)}{4.7244 \times 202.3} = 21.47^\circ$$

AOS to LOS error  $0.37^\circ$

4 RPM Nominal Scanner No. 9      50 Hz Clock

True spin period 14.8911 sec.      True RPM 4.03

True clock 50.58 Hz

AOS count  $256 + 128 + 32 + 2 = 418$

$$(200.4^\circ) \text{ AOS angle } \frac{418 \times 360}{14.891 \times 50.58} = 199.79^\circ$$

AOS error  $200.4 - 199.79 = 0.61^\circ$

AOS to LOS count  $32 + 8 + 4 + 2 = 46$

$$(21.1^\circ) \text{ AOS to LOS angle } \frac{(46-1)(360)}{14.891 \times 50.58} = 21.51^\circ$$

AOS to LOS error  
 $21.51 - 21.1 = 0.41^\circ$

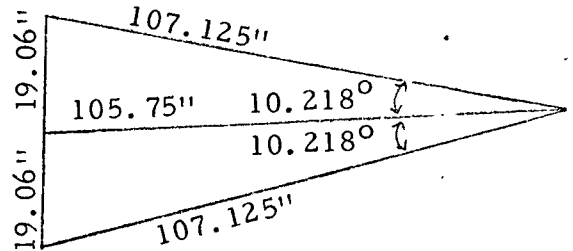
5.1.2 Spherical Mode Elevation Angles Scanner No. 9 November 10, 1972

Range geometry angles

Start of target elevation angle -  $10.218^{\circ}$

End of target elevation angle +  $10.218^{\circ}$

Start of target to end of target angle



<u>PAS Readout</u>	<u>Count</u>	<u>Angle</u>		<u>Error</u>
AOS 110100001	498	$350.156^{\circ}$	$349.782^{\circ}$	$.374^{\circ}$
LOS 000100000	15	$10.547^{\circ}$	$10.218^{\circ}$	$.329^{\circ}$
AOS to LOS	29	$20.391^{\circ}$	$20.436^{\circ}$	$.045^{\circ}$

\*Scanner mounting to turntable offset approximately  $1^{\circ}$

5.1.3 Verified spherical mode operation with tolerances \_\_\_\_\_ ( )

\*Mounting holes (2 ea) scanner #9 will be offset to provide correct alignment. (ACD)

Sun slit sensor will be shimmed to correct for the misalignment of the scanner to give a parallel condition to the 2 axis. (ACD)

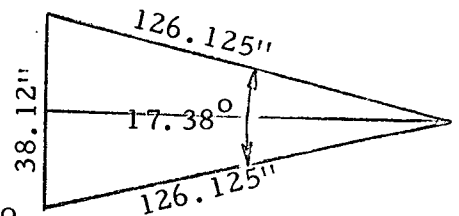
5.2 Planar Mode Elevation Angles

Range geometry angles

Start of target elevation angle  $90.0^{\circ} + 18.85^{\circ} = 108.85^{\circ}$

End of target elevation angle  $90.0^{\circ} + 36.4^{\circ} = 126.4^{\circ}$

Start of target to end of target angle  $17.55^{\circ}$  ( $17.38^{\circ}$  measured by tape)



<u>PAS Readout</u>	<u>Count</u>	<u>Angle</u>	<u>Error</u>
AOS $128 + 16 + 8 + 3 =$	155	108.984	$0.13^{\circ}$
LOS $128 + 32 + 16 + 4 =$	180	126.563	$0.16^{\circ}$
AOS to LOS	25 steps	17.578	$0.198^{\circ}$

Verified planar mode operation within tolerances \_\_\_\_\_ ( )

5.3 Solar Response Width of Scanner Scanner No. 9 November 8, 1972

Determine the solar response width of the scanner in degrees by slowly

scanning across a simulated sun source.  $137.3^{\circ} - 136.75^{\circ} = 0.55^{\circ}$

$90^{\circ}$  Solar Vector

Solar response width 0.55 degrees total width.

Retest November 10, 1972:  $0.65^{\circ}$  total width.

5.4 System calibration procedure completed

System calibration acceptable

\_\_\_\_\_ ( )

CALIBRATION REPORT

Nov 8 1972

5.1 Spherical Mode Scanner No 9 , Flight Electronics

5.1.1 Azimuth Angles (X-Y plane)

Spin Period Measurement Accuracy Test

(Clock frequency derived from PAS test set)

Nominal 50 RPM

Nominal 800 Hz Clock



True spin period 1.1636 sec True RPM

AOS count for full revolution  $512 + 256 + 128 + 32 + 8 + 4 + 2 = 942$

True clock frequency 809.28  $\rightarrow$  809.38 rechecked value



Spin period determined by PAS 1.16399  $\rightarrow$  1.16385

Fractional error .0004 .00025

$$\frac{.0004}{1.16} = .04\%$$

$$\frac{.00025}{1.16} = .022\%$$

Nominal 12 RPM

4.74356

Nominal 200 Hz Clock



True spin period ~~4.80039~~ True RPM

AOS count for full revolution  $512 + 256 + 128 + 64 = 960$

True clock frequency 202.3



Spin period determined by PAS 4.7454 - 4.7435

Fractional error .0019

$$\frac{.0019}{4.7} = .04\%$$

Nominal 4 RPM

Nominal 50 Hz Clock



True spin period 14.8423 True RPM

AOS count for full revolution  $512 + 128 + 64 + 32 + 8 + 4 + 2 = 750$

True clock frequency ~~202.3~~ 50.58



Spin period determined by PAS 14.828

Fractional error  $14.842 - 14.828 = .014$

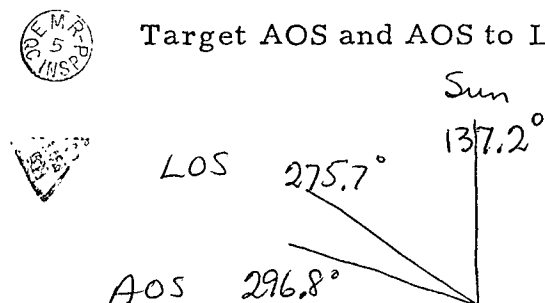
$$\frac{.014}{14.8} = .095\%$$

CALIBRATION REPORT

5.1 Spherical Mode

5.1.1 Azimuth Angles (X-Y plane)

Target AOS and AOS to LOS Measurement Accuracy Test



Range angles

Scanner direction at sun pulse - zero ref. 137.2°  
 Scanner direction at start of target ~~137.2°~~  $137.2 + (360 - 296.8) = 200.4°$   
 Scanner direction at end of target ~~275.7°~~  $137.2 + (360 - 275.7) = 221.5°$   
 AOS to LOS angle  $296.8 - 275.7 = 21.1°$

Angle Determinations by PAS System

50 RPM Nominal Scanner No 9 800 Hz Clock

True spin period  $\frac{1.23829}{1.23829} = 1.23829$  True RPM

True clock 809.38

AOS count  $\frac{557 \times 360}{1.23829 \times 809.38} = 200.07$   $32 + 8 + 4 + 1 + 512 = 557$

AOS angle  $\frac{557 \times 360}{1.23829 \times 809.38} = 200.07$

AOS error  $200.4 - 200.07 = 0.33°$

$$32 + 16 + 8 + 4 + 1 = 61$$

AOS to LOS count

~~$$61 + 32 + 1 = 94$$~~

AOS to LOS angle

$$(61 - 1) \times 360 = 21.55$$

AOS to LOS error

$$1.23829 \times 509.38$$

$$21.55 - 21.1 = 0.45^\circ \text{ error}$$

12 RPM Nominal Scanner No 8 200 Hz Clock



True spin period 4.72437 sec True RPM

True clock 202.3 Hz

AOS count  $512 + 16 + 3 = 531$

$$200.4^\circ \text{ AOS angle } \frac{531 \times 360}{4.72437 \times 202.3} = 200.01^\circ$$

AOS error  $0.4^\circ$

AOS to LOS count  $32 + 16 + 8 + 2 = 58$

$$21.1^\circ \text{ AOS to LOS angle } \frac{(58 - 1) \times 360}{4.7244 \times 202.3} = 21.47^\circ$$

AOS to LOS error  $0.37^\circ$

4 RPM Nominal Scanner No 9 50 Hz Clock



True spin period 14.8911 sec ~~14.8923~~ True RPM

True clock ~~202.3 Hz~~ 50.58 Hz

AOS count ~~512 + 16 + 3 = 531~~  
~~256 + 128 + 32 + 2 = 418~~ 750

$$200.4^\circ \text{ AOS angle } \frac{418 \times 360}{14.891 \times 50.58} = 199.79^\circ$$

$$\text{AOS error } 200.4 - 199.79 = 0.61^\circ$$

AOS to LOS count  $32 + 8 + 4 + 2 = 46$

$$21.1^\circ \text{ AOS to LOS angle } \frac{(46 - 1) \times 360}{14.891 \times 50.58} = 21.51$$

$$\text{AOS to LOS error } 21.51 - 21.1 = 0.41^\circ$$

# 5.1.2 Spherical Mode Elevation Angles

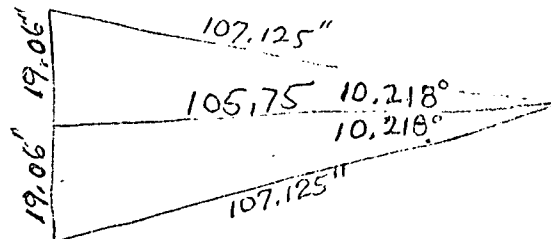
Scanner No 9 Nov 10 1972

Range geometry angles

Start of target elevation angle  $-10.218^\circ$

End of target elevation angle  $+10.218^\circ$

Start of target to end of target angle



PAS readout

Count

Angle

AOS 110100001

498

$350.156^\circ$

$349.782^\circ$  .324

LOS 000100000

15

$10.547^\circ$

$10.218^\circ$  .329

AOS to LOS

29

20.391

20.436 .045

\* Scanner mounting to turntable offset approx  $1^\circ$

5.1.3 Verified spherical mode operation with tolerances

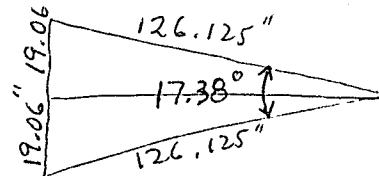
EMR-GC

24

11-10-72

\* Mounting holes (ZFA) scanner #9 will be offset to provide correct alignment (Q&D)

• Sun slit sensor will be shimmed to correct for the misalignment of the scanner to give a parallel condition to the Z axis. (Q&D)



## 5.2 Planar Mode Elevation Angles

Range geometry angles

Start of target elevation angle  $90.0^\circ + 18.85^\circ = 108.85^\circ$

End of target elevation angle  $90.0^\circ + 36.4^\circ = 126.4^\circ$

Start of target to end of target angle  $17.55^\circ$  ( $17.38^\circ$  measured by tape)

PAS readout	Count	Angle	error
AOS $128 + 16 + 8 + 3 = 155$		108.984	error = $0.13^\circ$
LOS $128 + 32 + 16 + 4 = 180$		126.563	error = $0.16^\circ$
AOS to LOS	25 steps =	17.578	error = $0.198^\circ$

Verified planar mode operation within tolerances                      (✓)

## 5.3 Solar Response Width of Scanner

Scanner No 9 Nov 8 1972

Determine the solar response width of the scanner in degrees by slowly

scanning across a simulated sun source.  $137.3^\circ - 136.75^\circ = 0.55^\circ$

90° SOLAR VECTOR

Solar response width            degrees total width.

SOLAR RESPONSE WIDTH AT  $4.5^\circ$                      

SOLAR RESPONSE WIDTH AT  $135^\circ$                      

## 5.4 System calibration procedure completed

System calibration acceptable                      ( )

5.2 Planar Mode Elevation Angles

Range geometry angles

Start of target elevation angle

End of target elevation angle

Start of target to end of target angle

PAS readout

Count

Angle

NA

AOS

LOS

AOS to LOS

Verified planar mode operation within tolerances \_\_\_\_\_ ( )

5.3 Solar Response Width of Scanner

Scanner No 9 Nov 10 1972

*test* Determine the solar response width of the scanner in degrees by slowly scanning across a simulated sun source.

$$137.75^{\circ} - 137.10^{\circ} = 0.65^{\circ}$$

Solar response width 0.65 degrees total width.

EMI-QC.  
1A  
11-10-72



5.4 System calibration procedure completed

System calibration acceptable \_\_\_\_\_ ( )

CALIBRATION REPORT

5.1 Spherical Mode

5.1.1 Azimuth Angles (X-Y plane)

Range angles

Sun source to start of target

Sun source to end of target

Start of target to end of target

PAS readout	50 RPM		12 RPM		4 RPM	
	Count	Angle	Count	Angle	Count	Angle
AOS						
LOS						
AOS to LOS						
AOS no target						

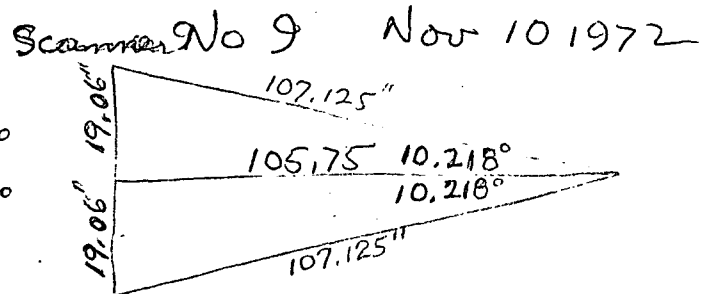
5.1.2 Spherical Mode Elevation Angles

Range geometry angles

Start of target elevation angle  $-10.218^\circ$

End of target elevation angle  $+10.218^\circ$

Start of target to end of target angle



PAS readout	Count	Angle	
AOS 1101000001	498	$350.156^\circ$	$349.782^\circ$ . 324
LOS 000100000	15	$10.547^\circ$	$10.218^\circ$ . 329
AOS to LOS	29	$20.391$	$20.436$ . 045

Scanner mounting to turntable offset approx  $1^\circ$

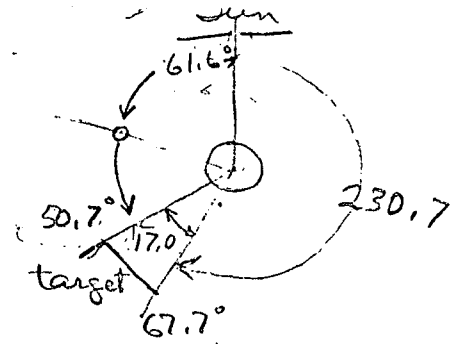
5.1.3 Verified spherical mode operation with tolerances

EMR-GC  
24  
11-10-72 ( )

Scanner No 1

$$\frac{360}{512} = .703125$$

$$\begin{array}{r} 67.7 \\ 129.3 \end{array} \begin{array}{r} 61.0 \\ 129.3 \end{array} \begin{array}{r} 230.7 \\ 230.7 \end{array}$$



## 5.2 Planar Mode Elevation Angles

Range geometry angles

Start of target elevation angle  $230.7^\circ$

End of target elevation angle  $247.7^\circ$

Start of target to end of target angle  $17.0^\circ$

PAS readout	Count	Angle
AOS	329	231.3
LOS	354	248.9
AOS to LOS		

SES



Verified planar mode operation within tolerances \_\_\_\_\_ ( )

## 5.3 Solar Response Width of Scanner

Determine the solar response width of the scanner in degrees by slowly scanning across a simulated sun source.

Solar response width \_\_\_\_\_ degrees total width.

## 5.4 System calibration procedure completed

System calibration acceptable \_\_\_\_\_ ( )

Contract No. NAS 5-11464

PANORAMIC ATTITUDE SENSOR FOR RAE-B  
LIFE TEST OF SCANNER MECHANISM

Prepared by

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December 1972

FINAL REPORT OF LIFE TEST

Prepared for

GODDARD SPACE FLIGHT CENTER  
Greenbelt, Maryland 20771

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle  Life Test of PAS Scanner Mechanism		5. Report Date December 1972	
		6. Performing Organization Code	
7. Author(s) M. P. Rebne Thomsen		8. Performing Organization Report No.	
9. Performing Organization Name and Address EMR Aerospace Sciences 5012 College Avenue College Park, Maryland 20740		10. Work Unit No.	
		11. Contract or Grant No. NAS 5-11464	
12. Sponsoring Agency Name and Address R.A.E. Project Office, Code 701.2 Goddard Space Flight Center Greenbelt, Maryland 20740 Art Davidson, Tech. Monitor		13. Type of Report and Period Covered Type II, Final Report of Life Test	
		14. Sponsoring Agency Code 701.2	
15. Supplementary Notes			
16. Abstract  An operational life test was performed on a mechanism identical with that used in the scanners of the Panoramic Attitude Sensor system for the RAE-B Spacecraft. The mechanism was operated for one-million revolutions of the optical encoder shaft, equivalent to one year's operation in space at the anticipated duty cycle. Gear train friction, backlash and other operating parameter were measured before and after the operating test, and the unit was examined visually for wear. Aside from one design defect in the encoder, which was corrected in the course of the test, the mechanism operated properly throughout the test, and all performance tolerances remained within the specified limits at the end of the test.			
17. Key Words		18. Distribution Statement	
19. Security Classif. (of this report) unclassified	20. Security Classif. (of this page) unclassified	21. No. of Pages	22. Price

Figure 2. Technical Report Standard Title Page

## PREFACE

A) Objective: The purpose of the PAS scanner mechanism life test was to determine whether this mechanism would continue to operate for one year in space and maintain accuracy within the specified limits.

B) Scope of Work: A scanner head mechanism was built and operated for  $1.0 \times 10^6$  revolutions of the encoder shaft. The mechanism was built with parts identical to those used in the flight scanners and included all moving/wearing parts of the scanner design. Mechanical tolerances, backlash and frictional torque were measured at the beginning and end of the test.

C) Conclusions: The mechanism operated reliably throughout the test and remained within specifications at the end of the test. However, there was significant visible wear of some of the gears by the end of the test.

D) Summary of Recommendations: The mechanism as designed appears to be entirely satisfactory for the anticipated period of operation -  $10^6$  revolutions or one year in space at the specified duty cycle. However, if appreciably longer life was required, some modification would be required to reduce the gear wear.

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4.3	<u>Final Measurement</u>
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SECTION 6	APPENDICES
6.1	<u>Life Test Plan</u>
6.2	<u>Life Test Procedure</u>
6.3	<u>Life Test Data</u>

The purpose of the PAS life test was to determine whether the mechanical components of the PAS system, which may be subject to wear during operation, can be expected to continue to operate and hold their accuracy within the required tolerances throughout the projected one year operating life of the PAS system. The components under test included all moving parts of the scanner mechanism: motor, gear train, and all bearings including the encoder bearings. The components tested were purchased to the same specifications and from the same production lots as the components to be used in the flight scanners. The encoder used in this test was the engineering prototype unit and contained lower reliability electronic components but was mechanically identical to the flight units.

Basically the test consisted of an initial measurement of gear train friction and backlash, operation equivalent to one year in space ( $1.0 \times 10^6$  revolutions of the encoder shaft) and a final measurement of the backlash and gear train frictional torque. During the operation the temperature was cycled between  $-20^{\circ}\text{C}$  and  $+60^{\circ}\text{C}$  and the system was instrumented to detect and count missed steps (cycles in which the encoder did not complete a full revolution on 512 motor drive pulses). In addition, motor current at 18V and threshold operating voltage were recorded daily.

## 2.0 LIFE TEST SCANNER MECHANISM

The PAS life test assembly consists of a PAS scanner frame to which were mounted a flight qualified motor, an engineering prototype encoder, and the three-stage 64 to one reduction gear train through which the stepper motor drives the encoder. Thus as the motor advances in 45 degree steps, the encoder advances in steps of 0.703 degree. In all mechanical specifications, the PAS Life Test Mechanism exactly duplicated the flight units. Except for the encoder, all components were purchased in the same lots and to the same specifications as the corresponding flight components. The encoder used was Baldwin's engineering prototype unit. It is mechanically identical to the flight units, but used electronic components of lower reliability rating.

### 3.0 TEST INSTRUMENTATION

Test instrumentation was required to perform the following functions:

- 1) Operate the stepper motor at 100 steps per second for a period of 5.12 seconds every 7 seconds. Motor pulses are counted to stop at exactly 512 corresponding to exactly one revolution of the encoder.
- 2) Count completed revolutions of the encoder and accumulate in a 6-digit register.
- 3) Read encoder output and sense for position zero. If at any time after completion of a 512 step pulse train the encoder is not on zero position, an off zero error is registered and accumulated in a four bit register.
- 4) Provide regulated operating power for the motor and electronics and measure accurately the voltages supplied.
- 5) Provide a controlled temperature environment capable of maintaining the test mechanism at  $-20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ ,  $+60^{\circ}\text{C} \pm 2^{\circ}\text{C}$  or at room temperature.
- 6) Measure the angular backlash of the gear train.
- 7) Measure the frictional torque of the gear train.

The instrumentation used to accomplish each of these functions was as follows:

- 1) The stepper motor was driven by the motor driver section of the PAS breadboard electronics. An open breadboard version of each section of the PAS electronics was built to test the circuit design prior to fabrication of the flight boards. This circuitry was completed and checked out before the start of the life test. The motor drive pulses were thus identical to those to be used in flight. The time per cycle, however, was cut to half (7.5 seconds instead of 15 seconds) to reduce the time required to run the life test.
- 2) A PAS test set was designed and built along with the PAS electronics to provide a means for checking out the functioning of all of the PAS circuitry, both in verifying the design at the breadboard stage and in checkout and calibration of the flight units. Among the capabilities of this test set is a light bank readout of the motor drive pulse train. By means of a relay and a photodetector on the most significant bit light, the 6-digit counter was activated once for each train of 512 motor pulses.
- 3) The PAS test set also includes a light bank which displays directly the gray code output of the shaft position encoder. A decoding circuit senses position zero (all bits zero). The test set includes a function to test for zero at the end of each motor drive pulse train, and an error light comes on if the encoder is off zero. Another photodetector, relay and 4-bit counter were set up to be actuated by this light and count errors.
- 4) Precision regulated supplies were used to provide the  $5 \pm .1$  volt logic power and the  $18 \pm .2$  volt motor power. Voltages were checked with a calibrated digital voltmeter.

- 5) A Delta Designs Temperature Test Chamber was used to provide the thermal environment. This chamber uses electrical heating and evaporating CO<sub>2</sub> cooling, both thermostatically controlled to provide high or low temperatures accurate to within about 1°C. A copper constantan thermocouple and potentiometer were used to monitor the temperature. A recording potentiometer was used to record the temperature history.
- 6) Angular backlash of the gear train was measured at the encoder shaft. A torque arm and mirror were fastened to the encoder shaft. A low power gas laser was used to provide a light beam which was reflected from the mirror onto the wall. Motion of the shaft was measured to within a few arc minutes as weights were alternately applied to one end or the other of the torque arm. The magnitudes of the weights -63.6 g and 127.2 g and the lengths of the torque arm were such that the torques amounted to 2.0 oz. in, applied alternately clockwise and counterclockwise. During these measurements the motor shaft was held stationary by the detenting action of the permanent magnet motor.
- 7) Frictional Torque of the gear train was measured with the motor removed from the system. A torque watch was connected to the encoder shaft and torque increased until rotation started.

## 4.0 DISCUSSION OF TEST

### 4.1 Initial Measurement

The PAS Life Test was officially started on March 28, 1972. The following initial measurements were made:

- 1) Motor holding torque: With the motor energized at  $18.0 \pm .1$  V in fixed position (not stepping), a torque watch was coupled to the motor shaft and turned until the motor broke away from that step position and rotated through a half revolution. About 20 determinations were made with values ranging from 0.85 to 1.05 oz. in. The most frequent and repeatable value was 0.98 - 0.99 oz. in.
- 2) Gear train frictional torque: The motor was removed from the assembly. A torque watch was coupled to the encoder shaft and torque applied until the first motion of a gear was seen. Measured values of torque varied from 1.4 to 2.7 oz. in. This variation appeared to be an actual variation in the frictional torque at different positions of the gears. A typical set of determinations at four encoder positions  $90^\circ$  apart were 2.2, 2.3, 2.2, 1.8 oz. in average value 2.1 oz. in.
- 3) Great train backlash: The motor was replaced in the scanner assembly and powered in a fixed position. The scanner frame was clamped to the bench and the mirror chip and torque arms attached to the encoder shaft. The 63.6 and 127.2 gram weights were applied alternately to the torque arms to give a torque of 2.0 oz. in., clockwise and counterclockwise. The position of the reflected laser spot was marked on a paper at a distance of 13 ft 11 inches from the mirror. The total range of motion

of the laser spot was 0.18 inch corresponding to an angular backlash of

$$\frac{0.18}{167 \times 2} = 5.4 \times 10^{-4} \text{ radian} = 1.85 \text{ minutes of arc}$$

- 4) Step repeatability: The weights were removed from the torque arms on the encoder shaft but the mirror was retained. The scanner was operated in planer mode, stepping through 512 steps and stopping on encoder zero position. The laser beam was again reflected from the mirror onto the wall at a distance of 167 inches. In 10 repetitions, the total range of stopping positions was 1/16 inch or  $\pm 1/32$  inch. Angular repeatability, full range

$$\frac{0.18}{167 \times 2} = 1.87 \times 10^{-4} \text{ radians} = 0.64 \text{ minutes of arc}$$

or  $\pm 0.32$  minutes of arc.

#### 4.2 Life Test Operation

Life test operation of the test scanner mechanism began on March 29 with the scanner at room temperature and both the revolution counter and error counter set to zero. On March 30, the first set of daily checks was performed. The scanner operation was inspected visually. The revolution count (number of revolutions of the encoder completed) and the error count were recorded. Motor power was interrupted during a motor drive cycle to verify operation of the error light. Motor operating current was measured at 18.0 volts, and the motor drive voltage was reduced to determine the lowest voltage at which the motor would operate without missing steps. All of the above tests were repeated daily and the results recorded on the PAS Life Test Operating Measurement Data Sheets which are reproduced in their entirety in Appendix C.

The scanner mechanism was operated in the thermal chamber, cycling between  $+60^{\circ}\text{C} \pm 2^{\circ}\text{C}$  and  $-20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ , with a period of 48 hours for a full cycle. The durations of the hot and cold cycle were approximately 19 hours hot followed by a 5-hour cooldown, then 13 hours cold and a gradual warmup to room temperature. The 13-hour duration of the cold cycle was determined by the life of one tank of liquid  $\text{CO}_2$  coolant. There was some tolerance in the duration of these hot and cold cycles, but by the end of the test the scanner had operated through more than 40 hot and 40 cold cycles. The daily checks were made sometimes with the system hot, sometimes with it cold and sometimes near room temperature. The temperature which is recorded on the data sheet is the temperature of the system at the time the checks were performed.

Twice during the test, errors were recorded on the error register. In one case these were traced to momentary power failures during the preceeding night, due to a severe thunderstorm. In the other case, however, the system continued to generate errors, and it was evident that something was radically wrong. The problem was traced to the optical code disc of the encoder which had come loose from the encoder shaft. This occurred on May 10, after completion of about 450,000 revolutions or 45% of the full test. At this point the life test was stopped and the encoder was removed and returned to the manufacturer (Baldwin Electronics) for further investigation of the failure and redesign of the encoder disc mounting.

Baldwin determined that the failure was due to a materials problem. The encoder disc made of acrylic plastic was simply bonded to a shaft hub with epoxy. This technique has worked very well with the usual glass discs. However, epoxy does not bond to the acrylic plastic as well as it does to glass, and the thermal cycling was enough to break it loose.

The disc mount was redesigned so that the disc is captive between two metal hubs bonded to the shaft, and in addition it is pinned to these hubs by three stainless steel pins. This modification was performed on the prototype encoder (and also on the flight encoders) and the prototype encoder was remounted in the life test scanner mechanism.

With the modified encoder, the life test operation was resumed on June 19 and completed without any other difficulty on August 11, 1972. There was no significant change in operation or operating variables as measured by the daily checks except that the minimum voltage to operate the motor decreased from about 9.5 volts at the beginning of the test to about 8.5 volts at the end of the test, presumably due to a decrease in the gear train frictional load.

#### 4.3 Final Measurement

After completion of the required  $1.0 \times 10^6$  encoder revolutions, the measurements of motor holding torque, gear train friction and backlash were repeated. Comparison of the results of these measurements with the initial measurements shows a definitely measurable reduction in friction and increase in backlash, but the backlash remained within the limiting tolerance of 0.10 degree, and the entire mechanism continued to function properly. Below is tabulated a comparison of the results of the initial and final measurements.

	<u>Initial</u>	<u>Final</u>
1) Motor holding torque @ 18.0 V	0.99 oz in	0.93 oz in
2) Gear train friction	1.4 to 2.7 oz in	0.3 to 0.8 oz in
3) Gear train backlash	1.8 arc minutes	4.05 arc minutes
4) Indexing repeatability	0.6 arc minutes	1.0 arc minutes

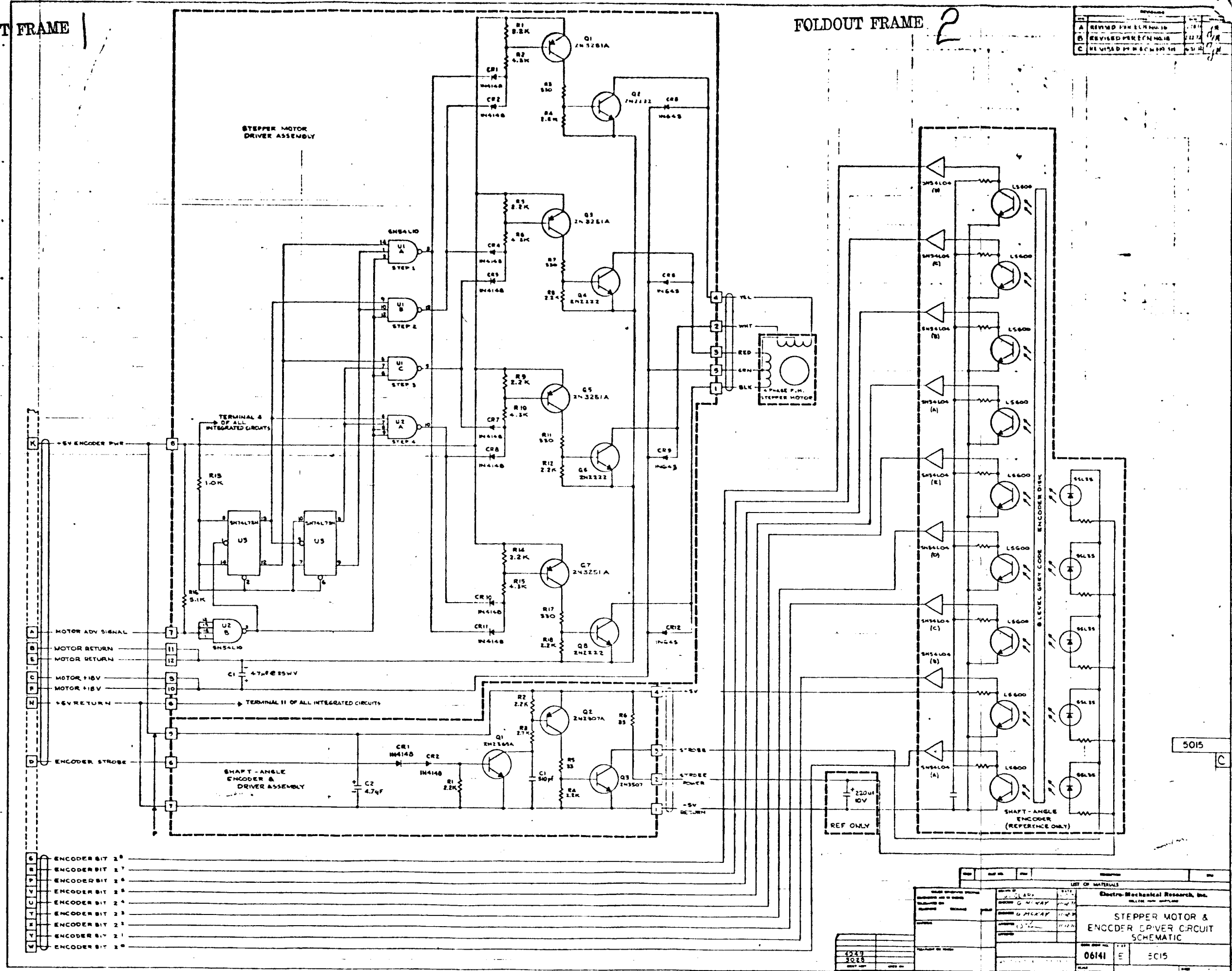
## 5.0 CONCLUSIONS

The conclusion to be drawn from this test is that the mechanical functions of the PAS system can be expected to function reliably and maintain their accuracy within the required tolerances for the projected life of the spacecraft - one year. This assumes the final design of the encoder is used with the disc pinned to the shaft hubs. At the end of the test, several of the gears showed significant wear. This was evident from the increased backlash, and could be seen by visual examination of the gears under a microscope. If an application is planned where the PAS scanner is required to operate appreciably more than  $10^6$  encoder revolutions, design modifications should be considered to reduce this wear.

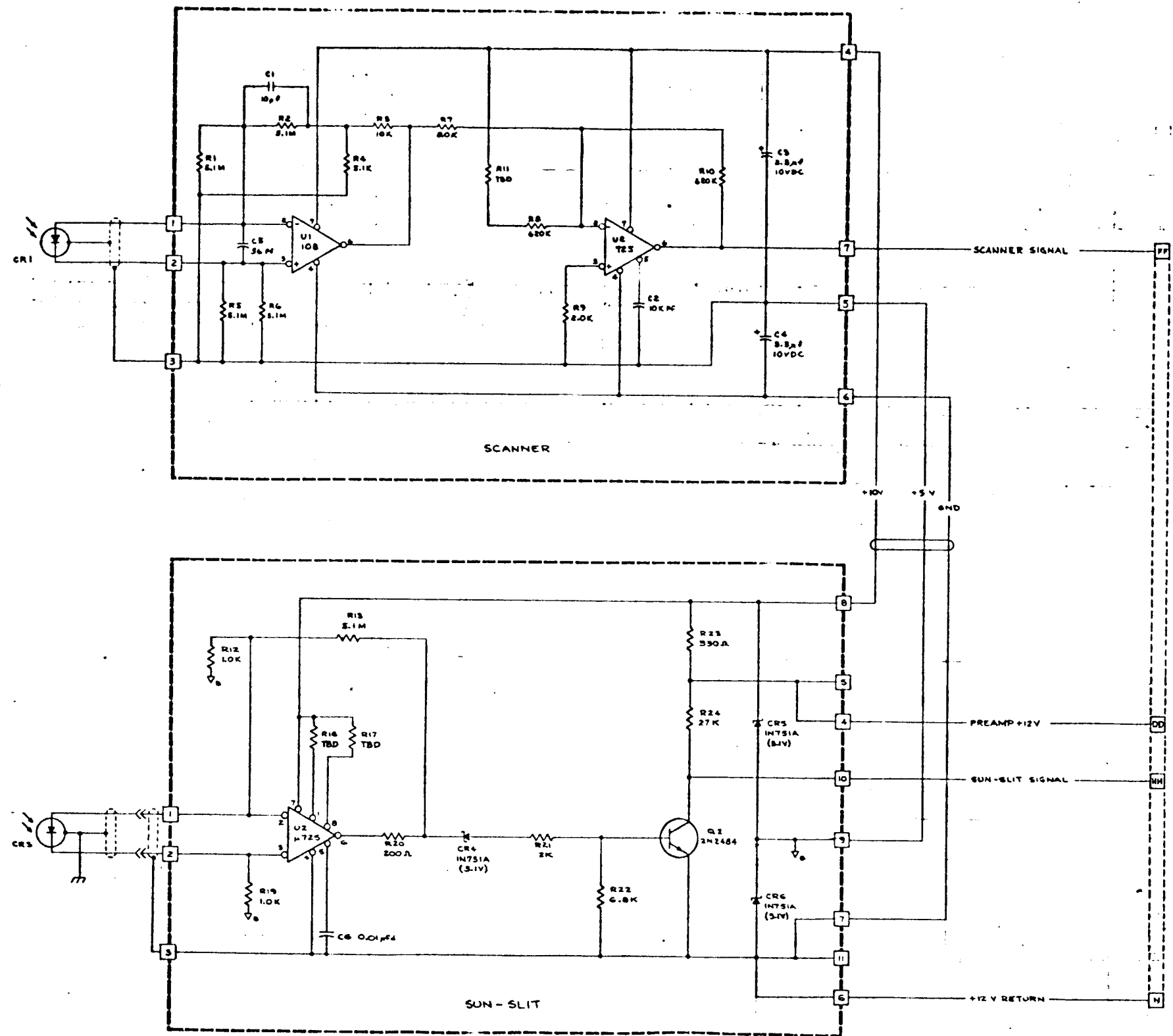
FOLDOUT FRAME

FOLDOUT FRAME 2

REV	REVISED BY	DATE	DESCRIPTION
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B	REVISED PER 1000-10	11/72	0/R
C	REVISED PER 1000-10	11/72	0/R



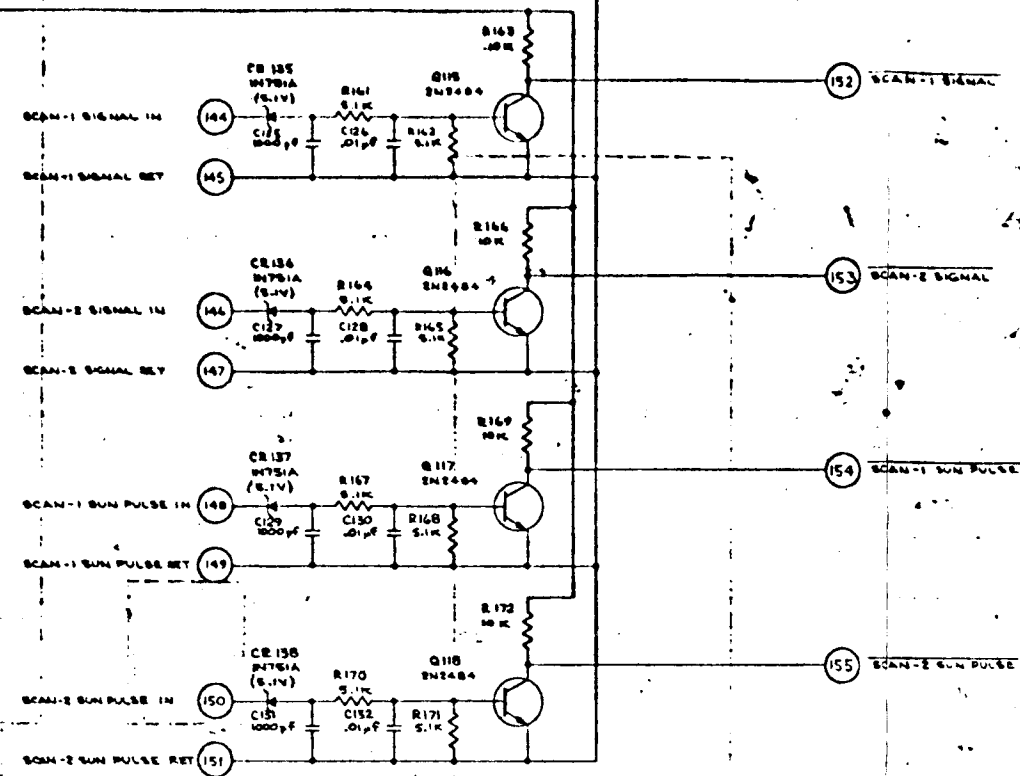
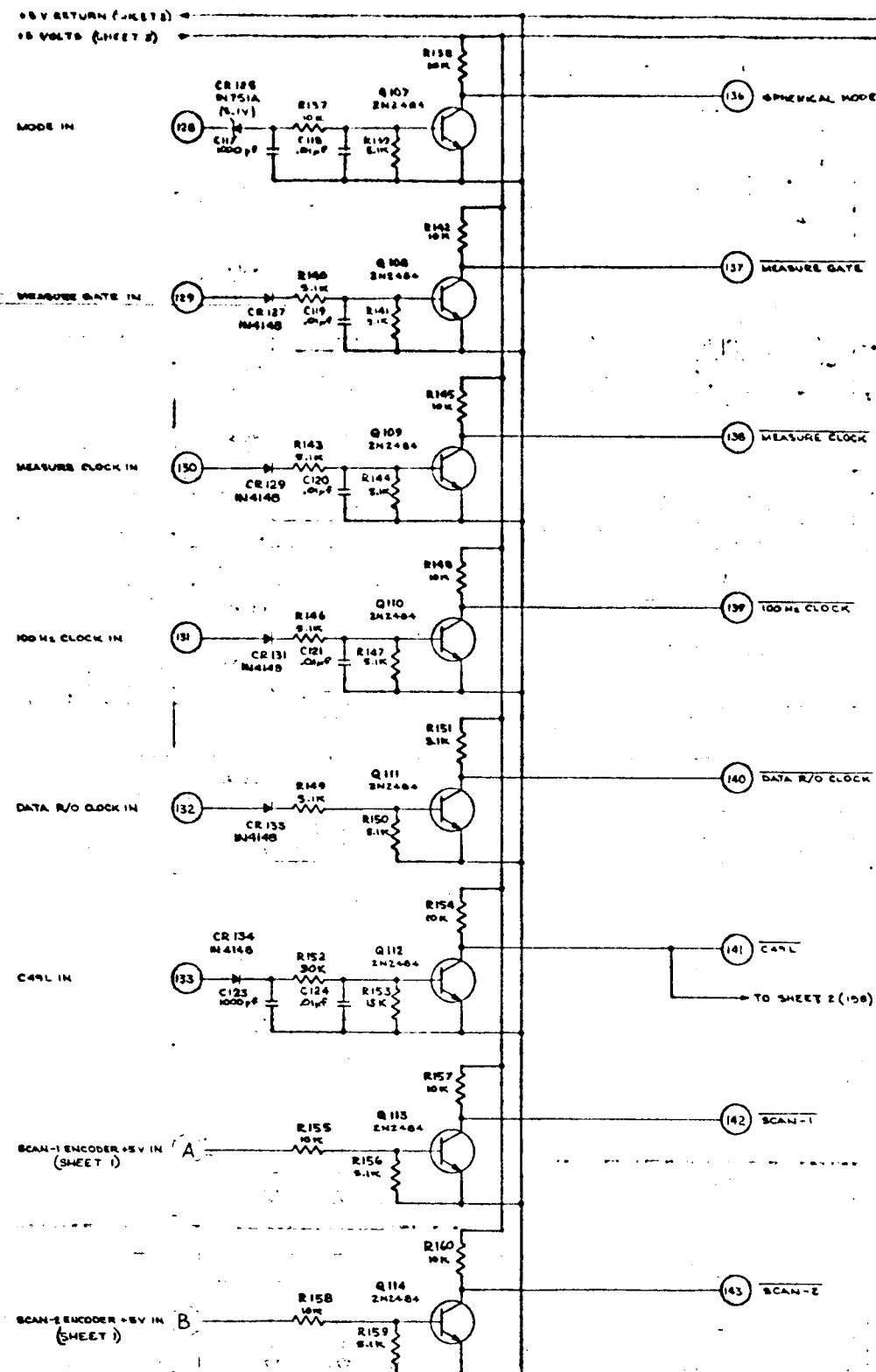
REVISED PER ECN NO. 10	10
REVISED PER ECN NO. 10	10
REVISED PER ECN NO. 10	10
REVISED PER ECN NO. 10	10



5013

D

LIST OF MATERIALS	
Electro-Mechanical Research, Inc.	
PAS SENSOR PREAMPS SCHEMATIC	
06141	E
5013	



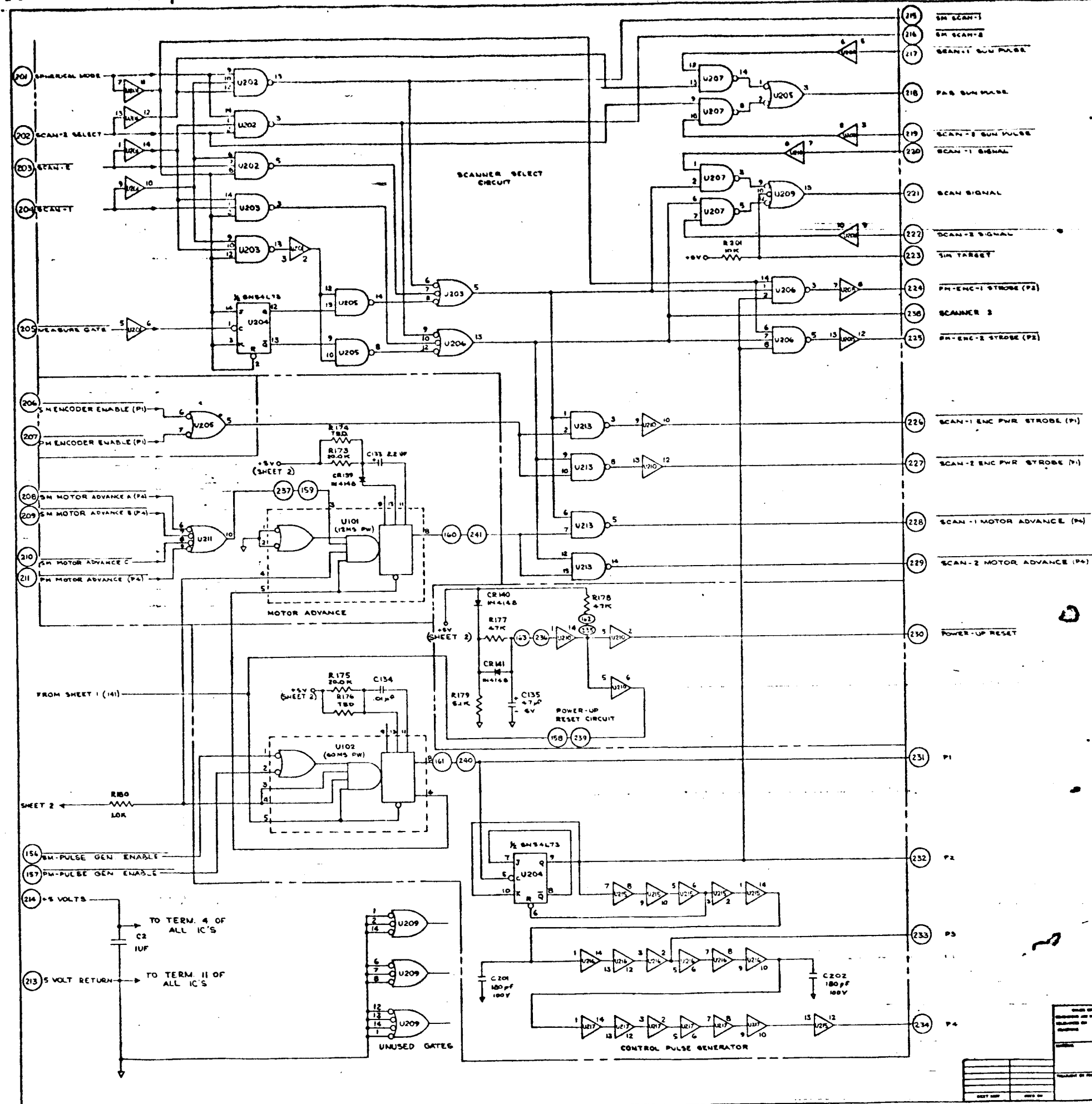
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B	REVISION PER 100% TESTS	10/1/66	JH
C	REVISION PER 100% TESTS	10/1/66	JH
D	REVISION PER 100% TESTS	10/1/66	JH
E	REVISION PER 100% TESTS	10/1/66	JH
F	REVISION PER 100% TESTS	10/1/66	JH
G	REVISION PER 100% TESTS	10/1/66	JH
H	REVISION PER 100% TESTS	10/1/66	JH
I	REVISION PER 100% TESTS	10/1/66	JH
J	REVISION PER 100% TESTS	10/1/66	JH
K	REVISION PER 100% TESTS	10/1/66	JH
L	REVISION PER 100% TESTS	10/1/66	JH

5016

INPUT CONDITIONING CIRCUITS

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Q108	2N2484	Q116	2N2484
Q109	2N2484	Q117	2N2484
Q110	2N2484	Q118	2N2484
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Q31			





SCANNER SELECT AND PULSE GENERATOR CIRCUITS

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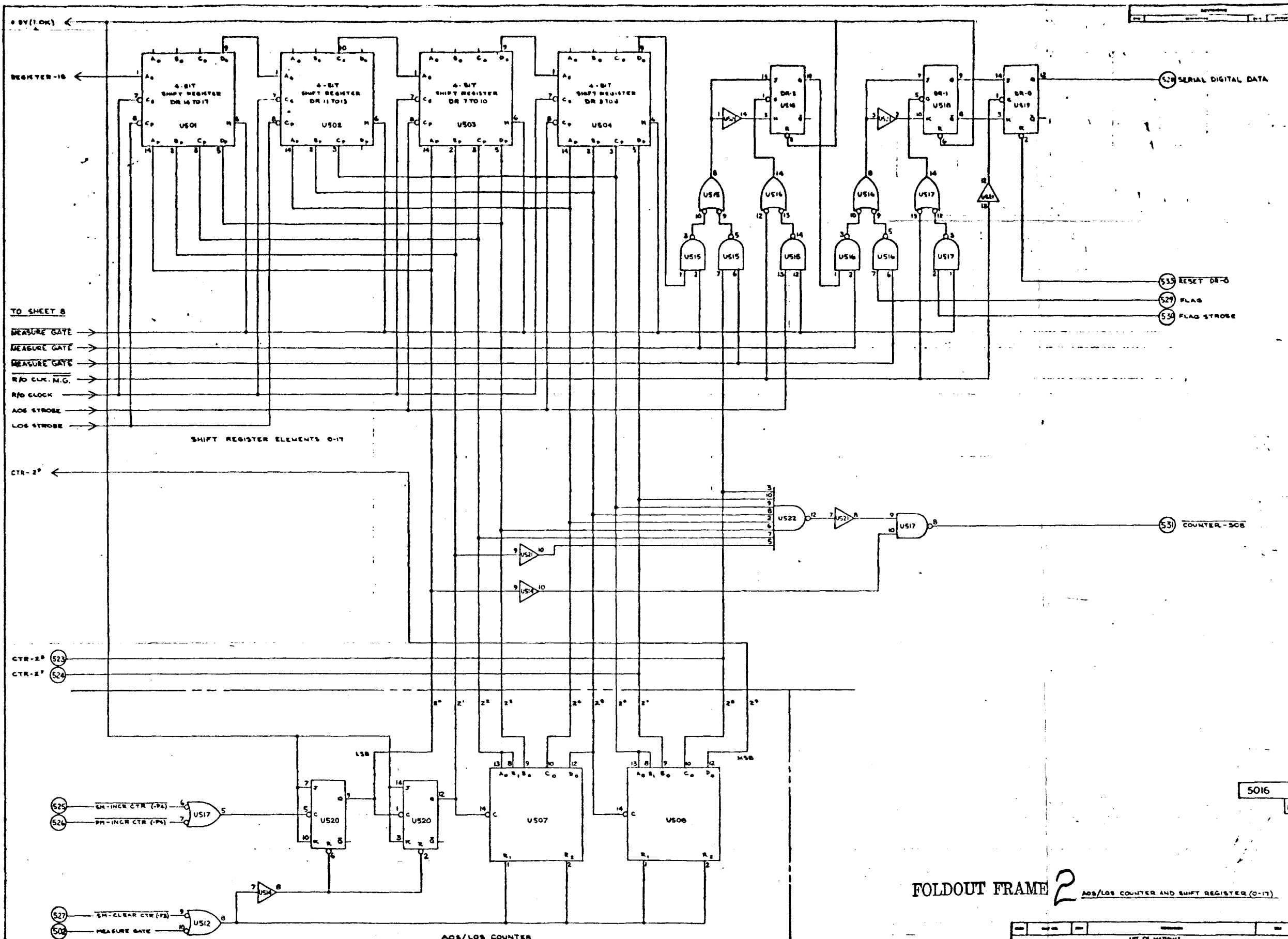
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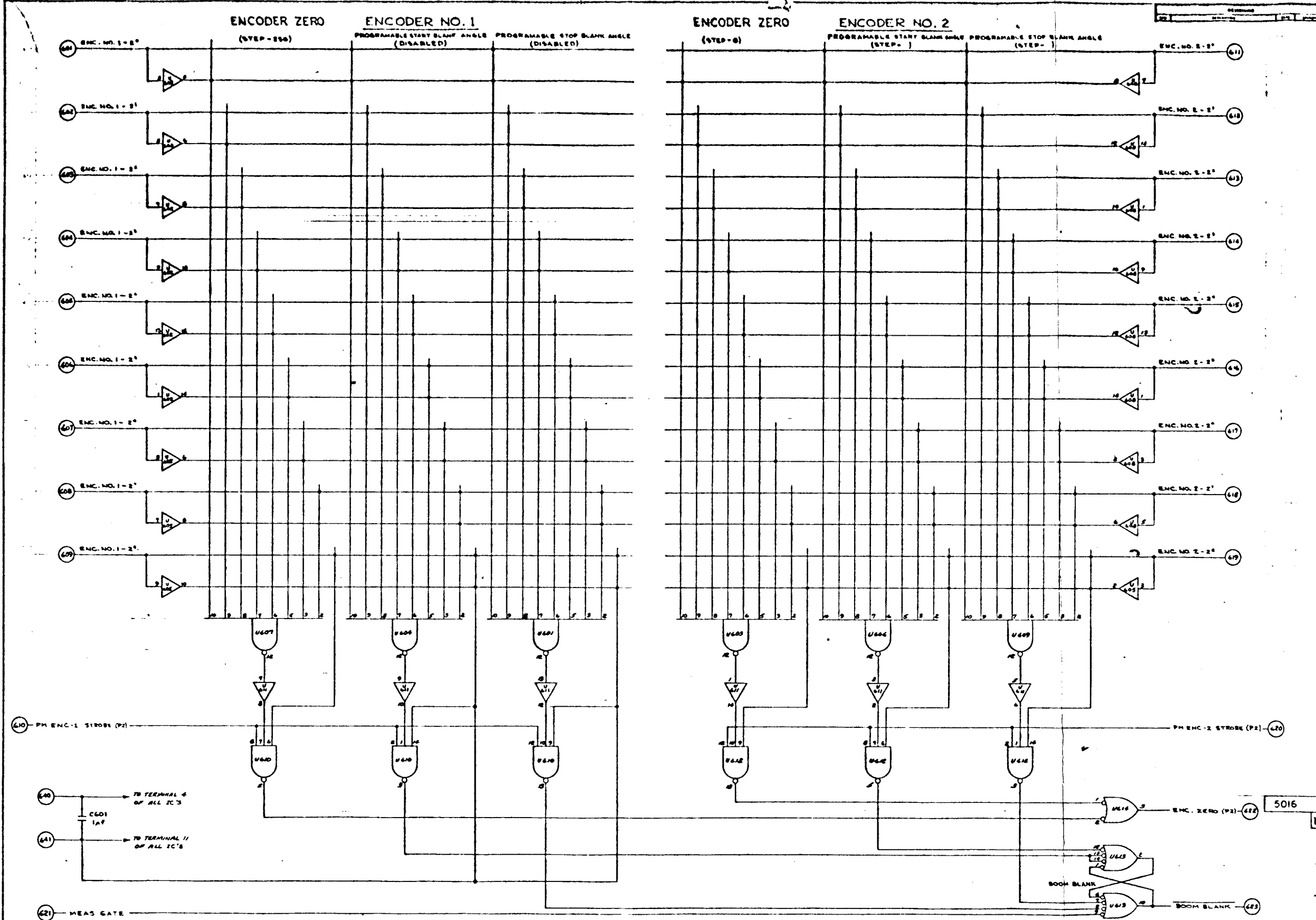


FOLDOUT FRAME 2 AOS/LOS COUNTER AND SHIFT REGISTER (0-17)

FOLDOUT FRAME

ELECTRONIC MODULE		P.A.S.	
SCHEMATIC DIAGRAM		5016	
DATE	11-27	FILE	06141 E
DESIGNED BY	G. M. KAY	REVIEWED BY	G. M. KAY
CHECKED BY	G. M. KAY	APPROVED BY	G. M. KAY
DATE	11-27	DATE	11-27
REVISION	1	REVISION	1
ELECTRONIC MODULE		P.A.S.	
SCHEMATIC DIAGRAM		5016	



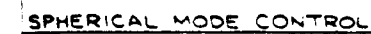


NOTES: UNLESS OTHERWISE SPECIFIED:  
1. + INDICATES P. C. BOARD PROGRAMMABLE  
INTER CONNECTION LOCATIONS.

ENCODER ZERO & BOOM BLANKING CKTS.

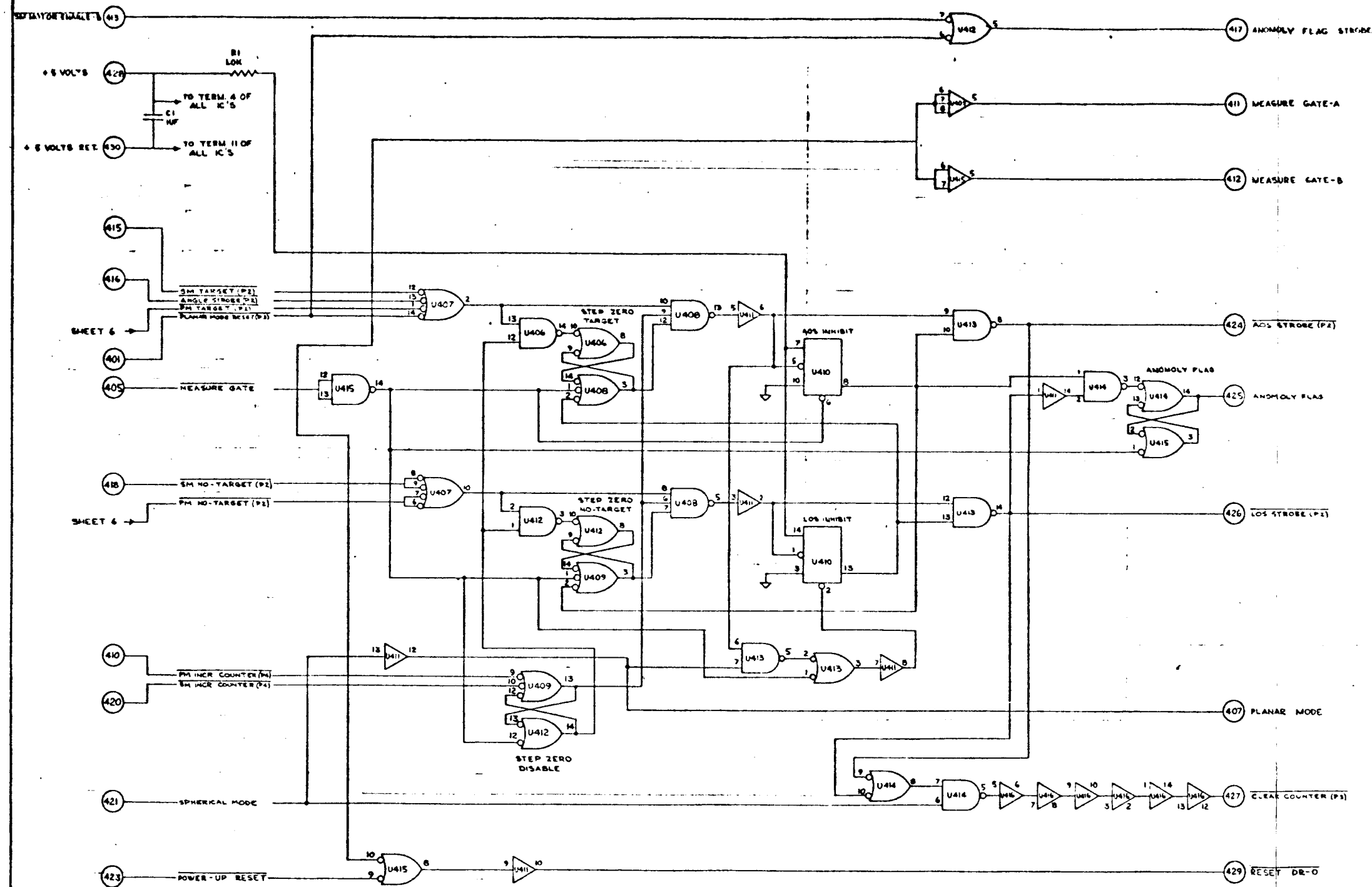
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57	10/1/68	G. MCKAY		
58	10/1/68	G. MCKAY		
59	10/1/68	G. MCKAY		
60	10/1/68	G. MCKAY		
61	10/1/68	G. MCKAY		
62	10/1/68	G. MCKAY		
63	10/1/68	G. MCKAY		
64	10/1/68	G. MCKAY		
65	10/1/68	G. MCKAY		
66	10/1/68	G. MCKAY		
67	10/1/68	G. MCKAY		
68	10/1/68	G. MCKAY		
69	10/1/68	G. MCKAY		
70	10/1/68	G. MCKAY		
71	10/1/68	G. MCKAY		
72	10/1/68	G. MCKAY		
73	10/1/68	G. MCKAY		
74	10/1/68	G. MCKAY		
75	10/1/68	G. MCKAY		
76	10/1/68	G. MCKAY		
77	10/1/68	G. MCKAY		
78	10/1/68	G. MCKAY		
79	10/1/68	G. MCKAY		
80	10/1/68	G. MCKAY		
81	10/1/68	G. MCKAY		
82	10/1/68	G. MCKAY		
83	10/1/68	G. MCKAY		
84	10/1/68	G. MCKAY		
85	10/1/68	G. MCKAY		
86	10/1/68	G. MCKAY		
87	10/1/68	G. MCKAY		
88	10/1/68	G. MCKAY		
89	10/1/68	G. MCKAY		
90	10/1/68	G. MCKAY		
91	10/1/68	G. MCKAY		
92	10/1/68	G. MCKAY		
93	10/1/68	G. MCKAY		
94	10/1/68	G. MCKAY		
95	10/1/68	G. MCKAY		
96	10/1/68	G. MCKAY		
97	10/1/68	G. MCKAY		
98	10/1/68	G. MCKAY		
99	10/1/68	G. MCKAY		
100	10/1/68	G. MCKAY		

Electro-Mechanical Research, Inc.  
ELECTRONIC MODULE  
P. A. S.  
SCHEMATIC DIAGRAM  
06141 E 5016



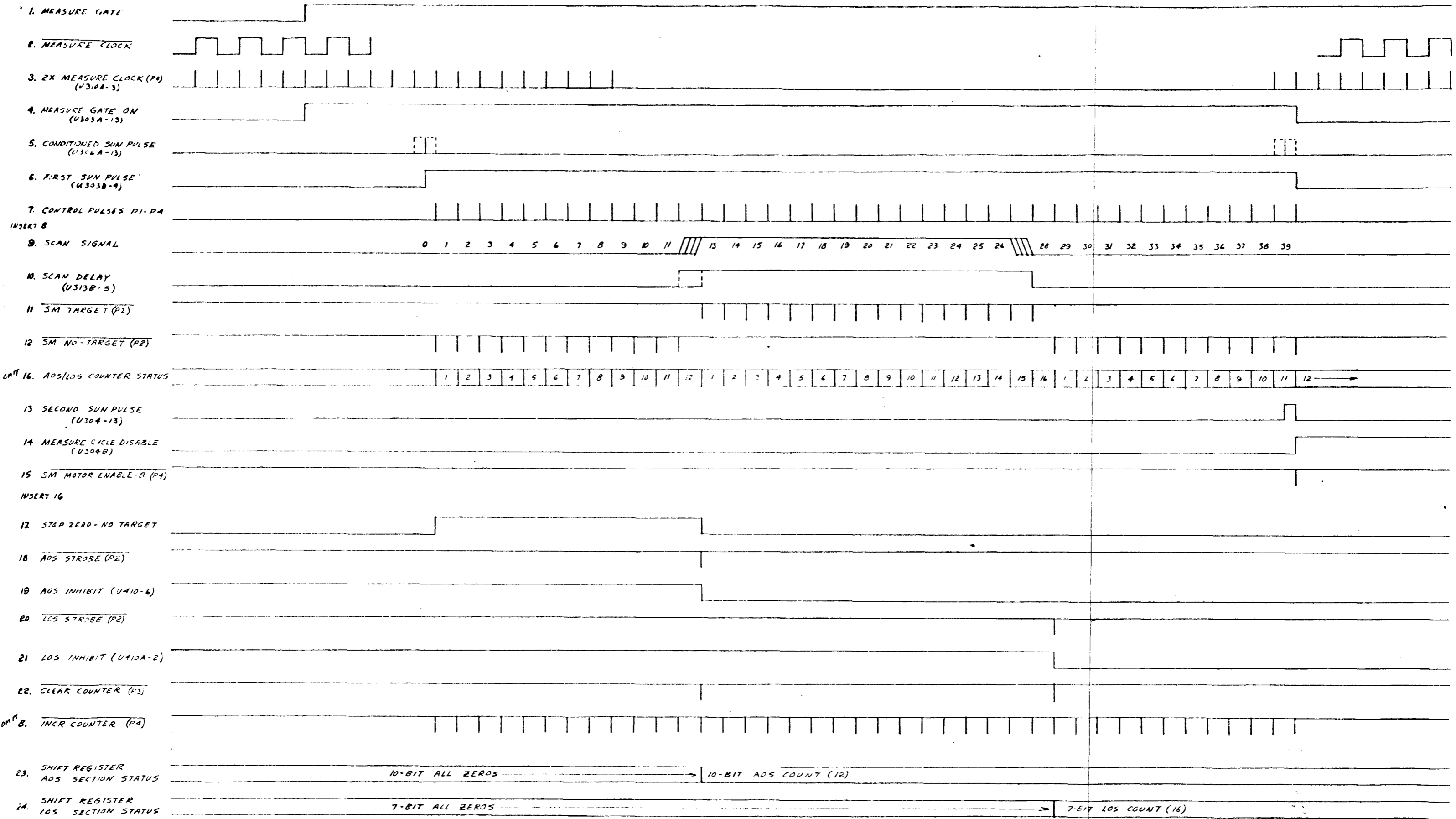
1





AOS/LOS STROBE GENERATOR

LIST OF MATERIALS			
ITEM	QTY	DESCRIPTION	UNIT
1	1	Electro-Mechanical Research, Inc.	
2	1	Electronic Module	
3	1	P.A.S.	
4	1	SCHEMATIC DIAGRAM	
5	1	06141	
6	1	5016	



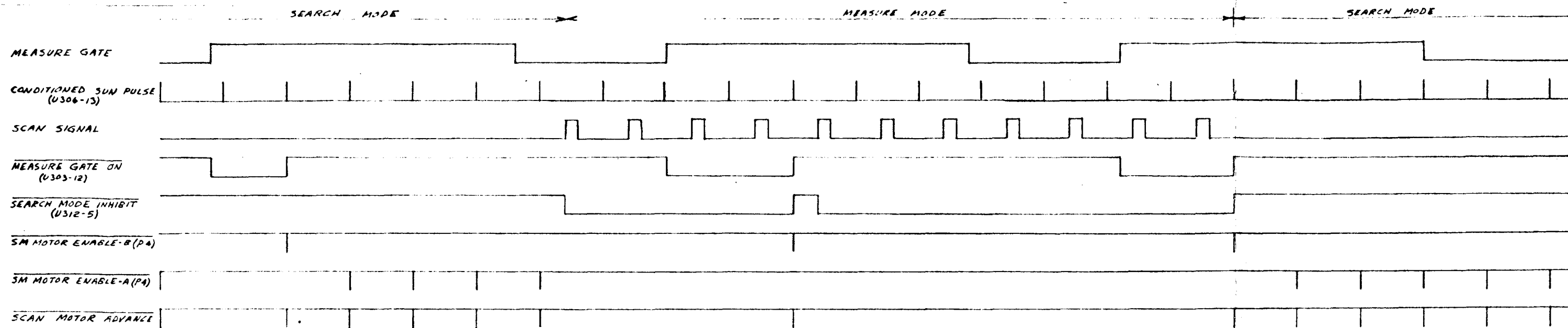


FIGURE F-12 SPHERICAL MODE SCANNER ADVANCE TIMING

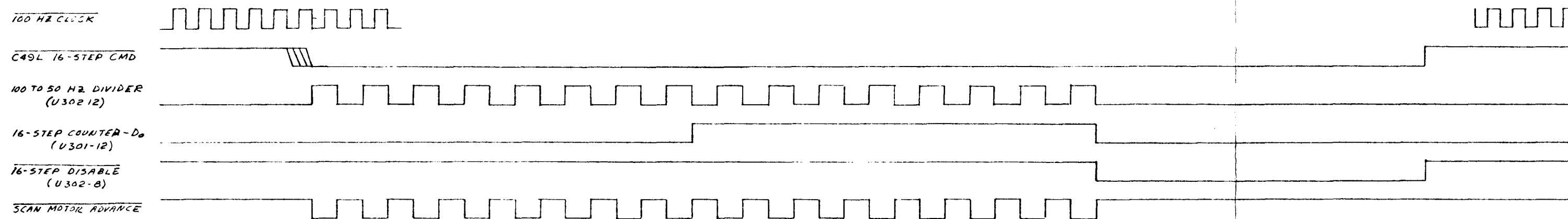


FIGURE F-13 SPHERICAL MODE 16-STEP ADVANCE TIMING

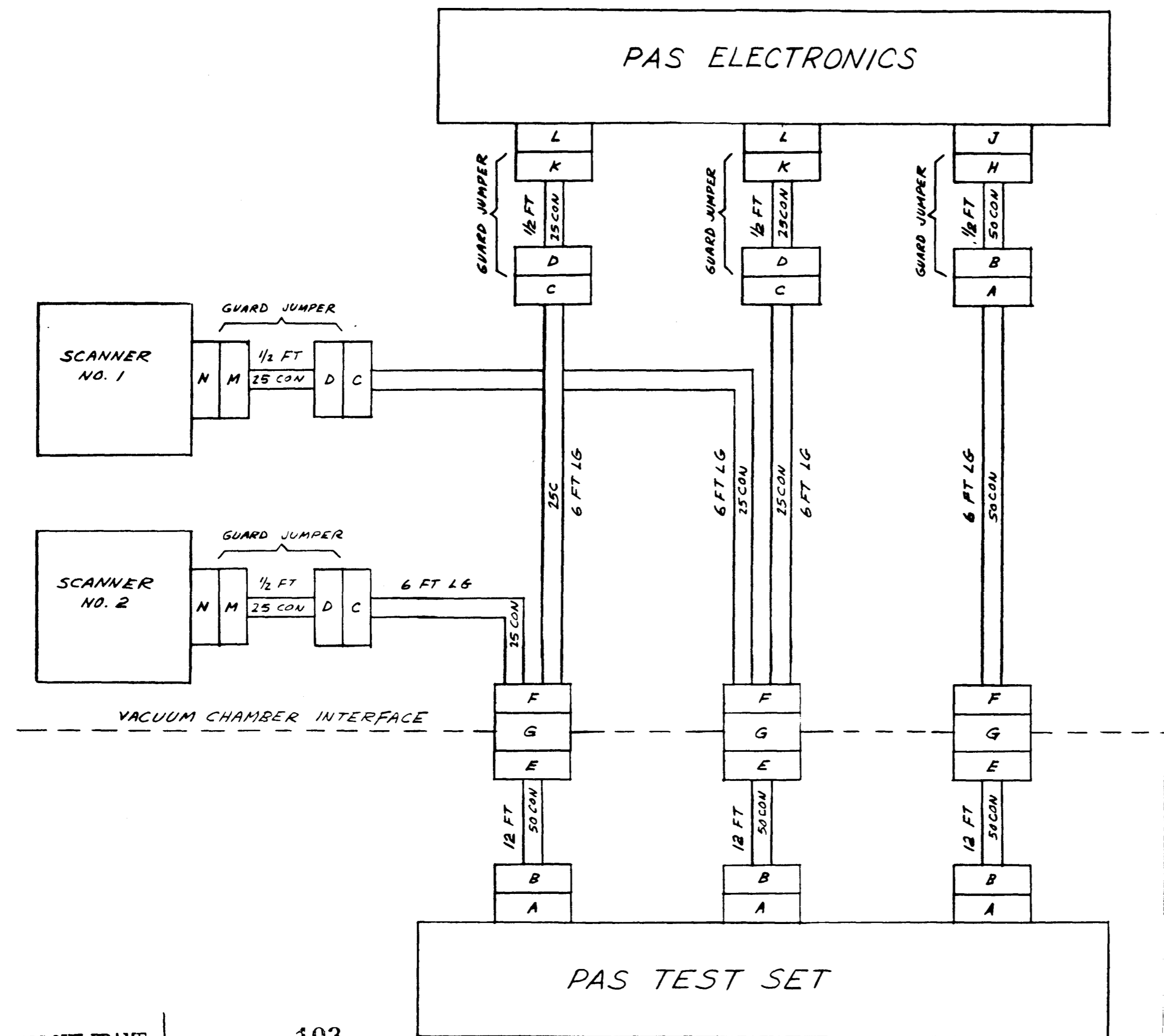


TEST PT	CANNON 50P CON.
PAS TEST SET	
	100 HZ CLOCK OUT 25
	DIGITAL DATA IN 24
	MEASURE CLOCK OUT 23
	MEASURE GATE OUT 22
	READOUT CLOCK OUT 21
	MODE CONTROL OUT 20
	+12V RELAY POWER OUT 19
	IIA-DIA-1 IN 18
	+12V ELEX PWR OUT 17
	+5V LOGIC PWR OUT 16
	+10V MOTOR PWR OUT 15
	C46L OUT 14
	C47L OUT 13
	C48L OUT 12
	C49L OUT 11
	SUN PULSE IN 10
	SEL SUN PULSE OUT 9
	F159 OUT 8
	F160 OUT 7
	5 V THRESHOLD OUT 6
	+12V RELAY PWR RETN 5
	+12V +5V P.W.R. RETN 4
	GND 3
	GND 2
	+10V MOTOR PWR RETN 1

CANNON 505 CON.		TEST	
25	100 HZ CLOCK IN	1-25	-
24	DIGITAL DATA OUT	1-24	1-52
23	MEASURE CLOCK IN	1-23	-
22	MEASURE GATE IN	1-22	
21	FEADOUT CLOCK IN	1-21	
20	MODE CONTROL IN	1-20	
19	+12V RELAY PWR IN	1-19	1-37
18	11A-C/A-1 OUT	1-18	1-36
17	+12V ELEX PWR IN	1-17	
16	+5V LOGIC PWR IN	1-16	
15	+18V MOTOR PWR IN	1-15	1-28
14	C46L IN	1-14	1-35
13	C47L IN	1-13	1-34
12	C43L IN	1-12	1-33
11	C49L IN	1-11	1-32
10	SUN PULSE OUT	1-10	1-46
9	SEL. SUN PULSE IN	1-9	1-45
8	F159 IN	1-8	1-31
7	F160 IN	1-7	1-30
6	SIM. TARGET IN	1-6	1-44
5	+12V RELAY PWR FET OUT	1-5	1-27
4	+12V, +5V PWR FET OUT	1-4	1-25
3	GND	1-3	1-42
2	GND	1-2	
1	+18V MOTOR PWR FET OUT	1-1	1-26

FOLDOUT FRAME 2

NEXT ASSY	USED ON



DISCRIPTION	C1	SOURCE	PIN NO.
DATA BIT 0 (ZERO)	L1	1	1
" " 1 (FLAG)	L2	2	2
" " 2 (AOS-B)	L3	3	3
" " 3 (" -7)	L4	4	4
" " 4 (" -6)	L5	5	5
" " 5 (" -5)	L6	6	6
" " 6 (" -4)	L7	7	7
" " 7 (" -3)	L8	14	24
" " 8 (" -2)	L9	13	25
" " 9 (" -1)	L10	12	26
" " 10 (" -0)	L11	11	27
" " 11 (LOS-6)	L12	10	28
" " 12 (" -5)	L13	9	29
" " 13 (" -4)	L14	8	30

DISCRIPTION	C2	SOURCE	PIN NO.
DATA BIT 14 (LOS-3)	L15	1	9
" " 15 (" -2)	L16	2	10
" " 16 (" -1)	L17	3	11
" " 17 (" -0)	L18	4	12
" " 18A (LOS-8)	L19	5	13
" " 19A (LOS-7)	L20	6	14
" " 20 (ENC-6)	L23	7	15
" " 21 (" -5)	L24	14	32
" " 22 (" -4)	L25	13	33
" " 23 (" -3)	L26	12	34
" " 24 (" -2)	L27	11	35
" " 25 (" -1)	L28	10	36
" " 26 (" -0)	L29	9	37
" " 27 (ZERO)	L30	8	38

DISCRIPTION	C3	SOURCE	PIN NO.
DATA BIT 13R (ENC-8)	L21	1	17
DATA BIT 13B (ENC-7)	L22	2	18
STEPPER DISPLAY-0	L39	3	19
" " -1	L38	4	20
" " -2	L37	5	21
" " -3	L36	6	22
" " -4	L35	7	23
" " -5	L34	8	24
" " -6	L33	9	25
" " -7	L32	10	26
" " -8	L31	11	27

B1 (TO TEST POINTS)			
100 HZ CLK	TPA-1	1	1
DIGITAL DATA	TPA-2	2	2
MEASURE GATE	TPA-4	3	3
DATA CLOCK	TPA-5	4	4
MODE CONTROL	TPA-6	5	5
ANALOG DATA	TPA-8	6	6
SUN PULSE	TPA-16	7	7
MEASURE CLOCK	TPA-3	8	30
SIGNAL GROUND	TPA-23	9	29
LOGIC GROUND	TPA-22	10	28
SIMULATED TARGET	TPA-20	11	27
FLAG #160	TPA-19	12	26
FLAG #159	TPA-18	13	25
SEL. SUN PULSE	TPA-17	14	24

B2 (FROM PANEL)			
MEASURE GATE	SW2A-C	1	9
11 SEC. MEASURE GATE	SW2A-1	2	10
12 SEC. MEASURE GATE	SW2A-3	3	11
MEASURE CLOCK OUT	SW2B-C	4	12
400 HZ CLOCK	SW2B-1	5	13
100 HZ CLOCK	SW2B-2	6	14
25 HZ CLOCK	SW2B-4	7	15
SCANNER 1 MOTOR PULSE	TPB-16	8	38
SCANNER 2 MOTOR PULSE	TPC-16	9	37
SIMULATOR MOTOR PULSE	TPD-16	10	36
CLEAR SW (C)	SW23(C)	11	35
		12	34
		13	33
		14	32

B3 (TEST PLATES)			
ENCODER-0	TPD-1	1	17
-1	TPD-2	2	18
-2	TPD-3	3	19
-3	TPD-4	4	20
-4	TPD-5	5	21
-5	TPD-6	6	22
-6	TPD-7	7	23
-7	TPD-8	8	24
-8	TPD-9	9	25
ENCODER STROBE	TPD-19	10	26
SCANNER SIGNAL	TPD-20	11	27
SCANNER RETURN	TPD-21	12	28
SUN SIGNAL	TPD-22	13	29
SUN RETURN	TPD-23	14	30

A1			
AOS SIM. BIT 8(H)	S24-H	1	1
" " 8(L)	S24-L	2	2
" " 8(C)	S24-C	3	3
" " 7(H)	S25-H	4	4
" " 7(L)	S25-L	5	5
" " 7(C)	S25-C	6	6
" " 6(H)	S26-H	7	7
" " 6(L)	S26-L	8	30
" " 6(C)	S26-C	9	29
" " 5(H)	S27-H	10	28
" " 5(L)	S27-L	11	27
" " 5(C)	S27-C	12	26
" " 4(H)	S28-H	13	25
" " 4(L)	S28-L	14	24

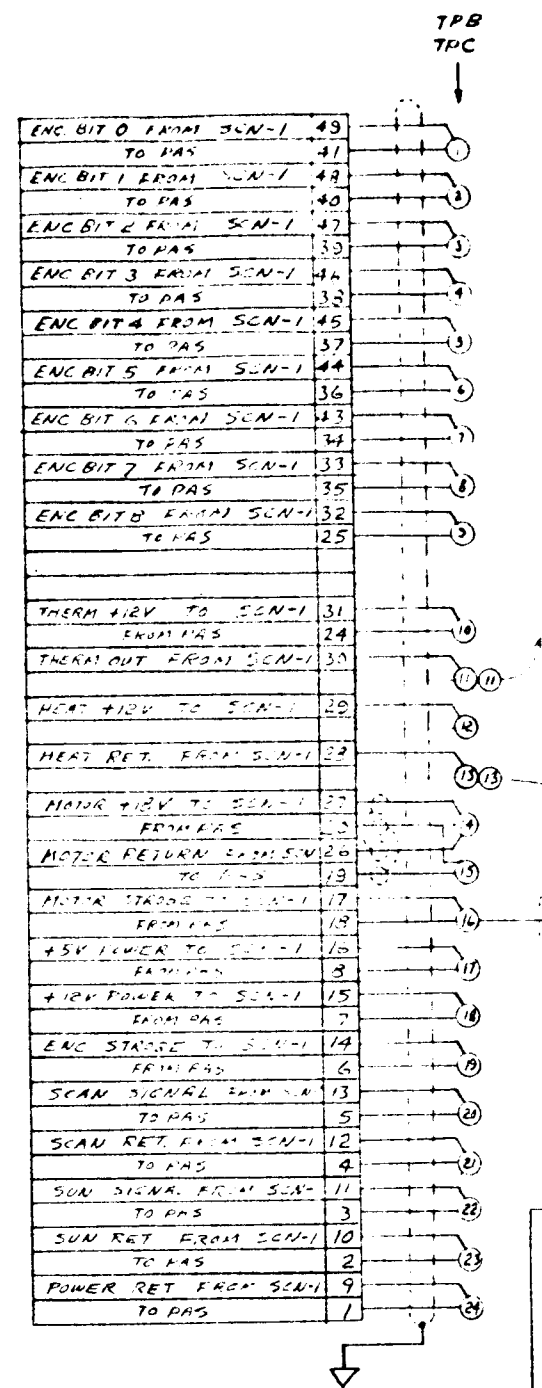
A2			
AOS SIM. BIT 4(C)	S28-C	1	9
" " 3(H)	S29-H	2	10
" " 3(L)	S29-L	3	11
" " 3(C)	S29-C	4	12
" " 2(H)	S30-H	5	13
" " 2(L)	S30-L	6	14
" " 2(C)	S30-C	7	15
" " 1(H)	S31-H	8	38
" " 1(L)	S31-L	9	37
" " 1(C)	S31-C	10	36
" " 0(H)	S32-H	11	35
" " 0(L)	S32-L	12	34
" " 0(C)	S32-C	13	33
LOS " 2(H)	S14-H	14	32

A3			
LOS SIM. BIT 8(L)	S14-L	1	17
" " 8(C)	S14-C	2	18
" " 7(H)	S15-H	3	19
" " 7(L)	S15-L	4	20
" " 7(C)	S15-C	5	21
" " 6(H)	S16-H	6	22
" " 6(L)	S16-L	7	23
" " 6(C)	S16-C	8	24
" " 5(H)	S17-H	9	25
" " 5(L)	S17-L	10	26
" " 5(C)	S17-C	11	27
" " 4(H)	S18-H	12	28
" " 4(L)	S18-L	13	29
" " 4(C)	S18-C	14	30

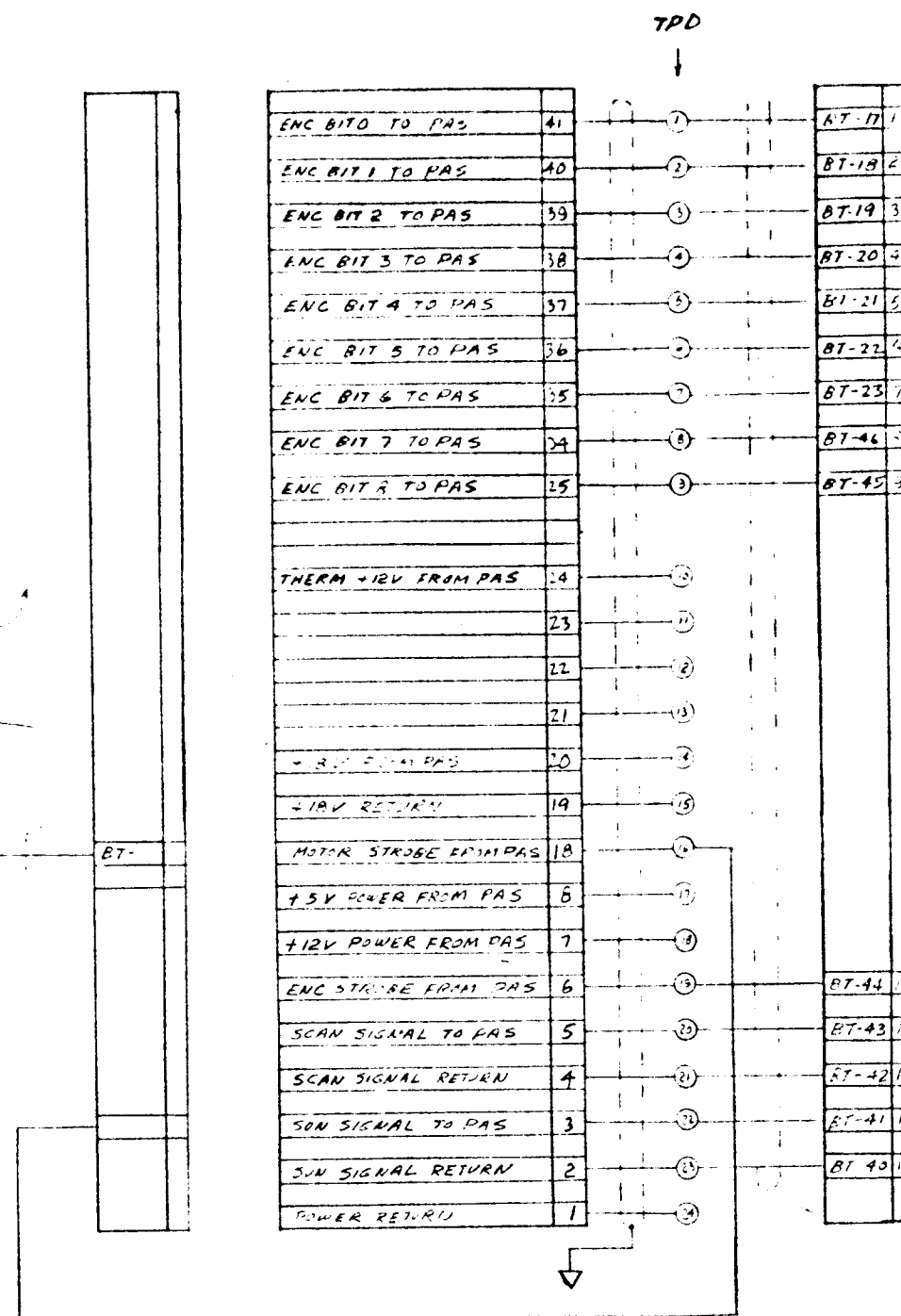
A13			
LOS SIM. BIT 3(H)	S19-H	1	1
" " 3(L)	S19-L	2	2
" " 3(C)	S19-C	3	3
" " 2(H)	S20-H	4	4
" " 2(L)	S20-L	5	5
" " 2(C)	S20-C	6	6
" " 1(H)	S21-H	7	7
" " 1(L)	S21-L	8	10
" " 1(C)	S21-C	9	11
" " 0(H)	S22-H	10	12
" " 0(L)	S22-L	11	13
" " 0(C)	S22-C	12	14
			15
			16

C11 (PANEL)			
SCANNER 1/2 SELECT CMD	SW13-F	1	1
SCANNER 1 ABLE CMD	SW12-H	2	2
SCANNER 2 ABLE CMD	SW11-H	3	3
16 STEP CMD	SW18-H	4	4
		5	5
		6	6
		7	7
		8	10
		9	11
		10	12
		11	13
		12	14
		13	15
		14	16

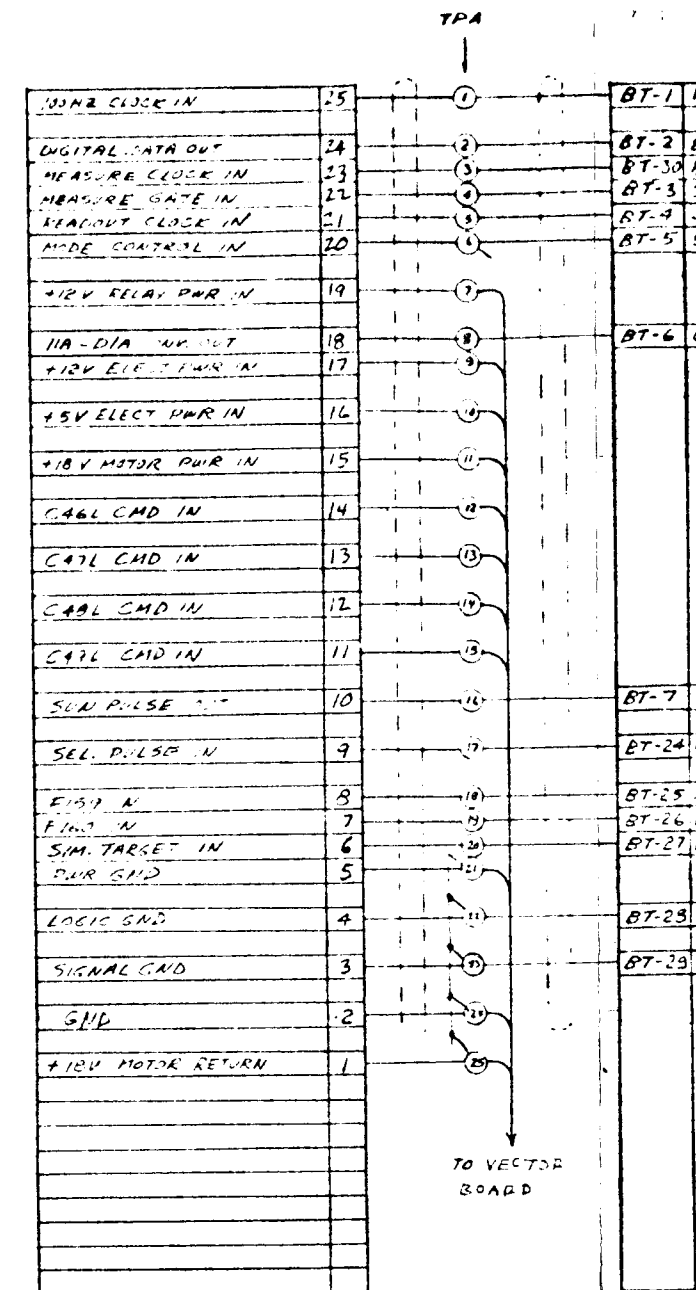
C26 (VECTOR BOARD)			
SCANNER 1/2 SELECT CMD	VB-1	1	1
SCANNER 1 ABLE CMD	VB-5	2	2
SCANNER 2 ABLE CMD	VB-9	3	3
16 STEP CMD	VB-13	4	4



SCANNER/PAS ELECTRONICS  
M RECEPTE  
(2 REQD)



SIMULATOR/PAS ELECTRONICS  
M RECEPICLE  
(1 REQ'D)



TEST SET / PAS ELECTRONICS  
F RECEPTICLE  
(1 REQ'D)

## FOLDOUT FRAME

## FOLDOUT FRAME

2

INCREASED CAPABILITY FOR THE  
PANORAMIC ATTITUDE SENSOR (PAS)

Technical Proposal for  
Contract Modification of  
NASA Contract NAS 5-11464

March 28, 1972

Prepared For:  
National Aeronautics and Space Administration  
Goddard Space Flight Center  
Greenbelt, Maryland

Prepared By:  
EMR-Aerospace Sciences  
EMR Division  
Weston Instruments, Inc.  
College Park, Maryland  
Phone 301-864-6340

## 1.0 INTRODUCTION

EMR proposes to make circuit modifications and additions to the PAS electronic circuitry as required by Modification No. 1 to Contract NAS 5-11464. These modifications are described below.

## 2.0 SPHERICAL MODE CHANGES

### 2.1 AOS and LOS Data Accuracy

The accuracy of the AOS and LOS counts will be doubled by circuit additions to perform the following functions:

- a. The measure clock input from the spacecraft will be doubled in frequency when the PAS is operating in the spherical mode.
- b. A tenth most significant bit will be added to the AOS/LOS counter.
- c. A tenth most significant bit will be added to the spherical mode AOS count in the shift register. See Tables 1 and 2.

The LOS count in the shift register will remain at 7 bits, thus an overflow can occur if the LOS count exceeds 127. Any ambiguity in the LOS count MSB will be resolved by GSFC. The new spherical mode measurement program is shown in Table 1.

### 2.2 Scanner Advance

With the proposed modifications, the step advance of a scanner in spherical mode will be as follows:

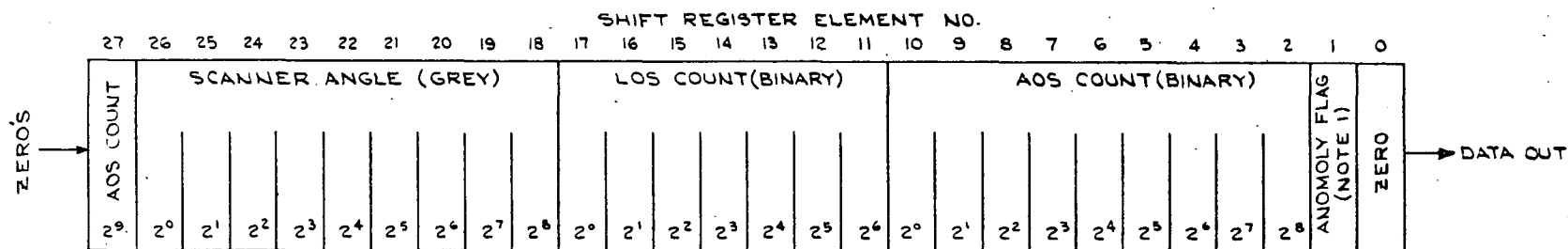
Until an illuminated target is detected, the scanner will operate in the search mode, advancing one step each time a sun pulse occurs, except the scanner does not advance on the sun pulse which

Meas. Gate Ms. Period (Sec)	Spacecraft Meas. Clock (Hz)	Spacecraft Spin RPM	PAS Meas. Clock (Hz)	Scan Angle Per Incre. (Deg)	Max. AOS Count **	Max. LOS Angle before overflow (Deg)
15.36	400	60	800	0.450	800	57.6
	400	50	800	0.375	960	48.0
	400	46.9*	800	0.352	1024	45.0
	100	50	200	1.500	240	192.0
	100	30	200	0.900	400	115.0
	100	12	200	0.360	1000	46.1
	100	11.7*	200	0.351	1024	45.0
46.08	25	12	50	1.440	250	184.0
	25	6	50	0.720	500	92.2
	25	3	50	0.360	1000	46.1
	25	2.93*	50	0.351	1024	45.0

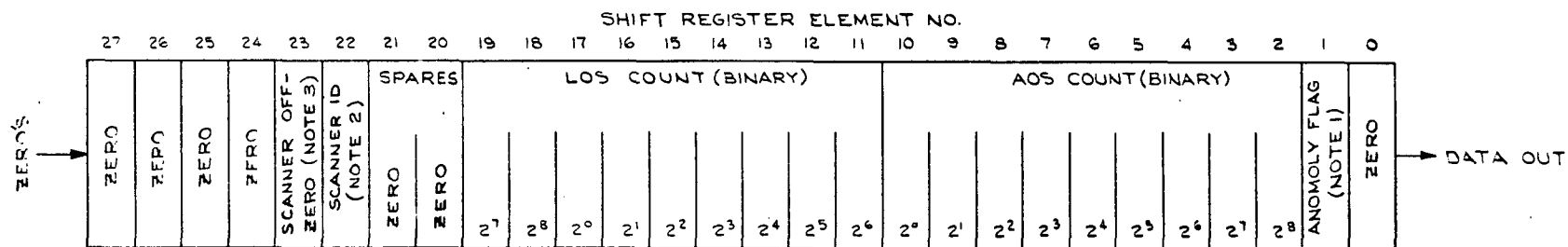
\* Minimum speed before possible AOS Data Overflow

\*\* When no scanner target is present

Table 1 Spherical Mode



### SPHERICAL MODE



### PLANAR MODE

#### Notes

1. Anomaly flag  
0 for no target at start of scan  
1 for target at start of scan
2. Scanner ID  
0 for scanner 1  
1 for scanner 2
3. Scanner off-zero  
0 when on zero at start of scan  
1 when off zero at start of scan

Table 2

begins each measure cycle. When a target is acquired, whether during the measure cycle or at any other time during the measure gate cycle, the scanner switches to the measure mode, and remains in the measure mode until the next end of measure cycle sun pulse occurs. While in the measure mode, no scanner advance occurs. However, at the end of each measure cycle, the scanner will switch from measure mode to search mode and advance a single step. If a target is again detected, it switches back to measure mode and performs another measurement during the next measure cycle.

Thus, in the presence of a continuous target, the scanner will advance one step and perform one measurement each measure gate cycle. When a target is intermittent, as in the case of spacecraft wobble, the probability of making a measurement is maximized because any target detected during a measure cycle is measured, whether it was detected during a preceding cycle or not. When no signal is acquired by the scanner during a measure cycle, the read out of the AOS will be the spin period (time from sun pulse to sun pulse).

This operation differs from that of the original design in the following respect: Originally, in the search mode, the scanner advanced on every sun pulse with no exceptions. A measurement was made only when a target was detected and the system was switched to the measure mode. Thus, targets acquired during a measure cycle were not measured until the following measure cycle. Therefore in case of spacecraft wobble or transient targets, a measurement might be lost.

### 3.0 PLANAR MODE CHANGES

#### 3.1 Target Qualification Circuit

EMR will make design changes and provide additional circuitry in the planar mode electronics to provide a target qualification circuit for the planar mode which has the following features:

- a. Accepts a "0 to 1" AOS transition only when the three scanner steps following the first "1" are also "1's."
- b. Accepts a "1 to 0" LOS transition only when the three scanner steps following the first "0" are also "0's."
- c. Qualification from scanner steps 509 through 512 are shown in the table below:

<u>Measurement Step</u>	<u>Following 3 Steps</u>		
509	510	511	512
510	511	512	512
511	512	512	512
512	512	512	512

Step 512 is at the same scanner position as step 0 but is measured 5.12 seconds later at the conclusion of the scanner cycle. Steps 509 through 512 can only be qualified by comparison with step 512 because the scanner has stopped in this position.

- d. The interaction between the boom inhibit circuit and the qualification circuit will be as follows. When the boom inhibit gate occurs, the target qualification circuit will maintain its status just prior to the inhibit. An example of this is provided in the table below. For this example, the boom inhibit circuit will inhibit scanner signals between increments 11 and 15.

Qualification Circuit					AOS/LOS	Scanner
<u>Measurement Step</u>	<u>Following 3 Steps</u>			<u>Counter Status</u>	<u>Step</u>	
5	6	7	8	5	8	
6	7	8	9	6	9	
7	8	9	10	7	10	
The status of the qualification circuit remains constant for the duration of the boom inhibit gate.				8	11	
				9	12	
				10	13	
				11	14	
7	8	9	10	12	15	
8	9	10	16	13	16	
9	10	16	17	14	17	
10	16	17	18	15	18	
16	17	18	19	16	19	
17	18	19	20	17	20	

When a transition occurs four or more increments before the boom inhibit, the transition is recorded for the interval during which it occurs. (Steps 5 through 7 of the above example). When a transition occurs within three steps of the boom inhibit, the transition cannot be validated until scanner signals following the boom inhibit become available to the qualification circuit. If four 1's or four 0's are present, the transition will be measured. However, because the AOS/LOS counter is not inhibited during the boom inhibit, the transition will be recorded as occurring at an increment equal to the measurement step interval plus the boom inhibit interval. In the above example, if a transition occurs at scanner step 8, the qualification circuit must wait until scanner step 16 before there is sufficient data available to qualify the transition. At this time, the AOS/LOS counter has advanced to a count of 13 which is equal to the transition step 8 plus the boom inhibit interval 5.

This offset in AOS or LOS can occur only for the three intervals preceding the boom inhibit gate and can easily be corrected in the data processing.

Transitions occurring after the boom inhibit zone are unaffected by the offset.

### 3.2 Transition Skipping Circuit

EMR will add additional circuitry to the planar mode control to accept only the first AOS transition and only the last LOS transition occurring during a scan cycle. This feature will improve the scanner operation when crossing the lunar terminator with its multiple light-dark transitions.

## 4.0 PAS SYSTEM REQUIREMENTS

### 4.1 Power

To accommodate the circuit modifications and additions discussed in this proposal, EMR requests that the +5 volt input power be increased to 1.0 watt. The +12 volt and +18 volt power requirements will be reduced to 0.20 watt at 12 V and 0.9 watt at 18 V.

### 4.2 Accuracy

Attitude data readouts of the PAS system modes will be within the following tolerances:

### Spherical Mode (Spin Mode)

<u>Azimuth Angles (X-Y plane)</u>					
<u>RPM</u>	<u>Clock</u>	<u>AOS</u>	<u>LOS</u>	<u>AOS to LOS</u>	<u>Spin Period</u>
50	800	$\pm .85^{\circ}$	$\pm .85^{\circ}$	$\pm 1.3^{\circ}$	.1%
12	200	$\pm .85^{\circ}$	$\pm .85^{\circ}$	$\pm 1.3^{\circ}$	.1%
4	50	$\pm 1.0^{\circ}$	$\pm 1.0^{\circ}$	$\pm 1.5^{\circ}$	.13%

### Elevation Angles (2-axis Ref.)

AOS  $\pm .45^{\circ}$

LOS  $\pm .45^{\circ}$

AOS - LOS  $\pm .9^{\circ}$

<u>Planar Mode (Z-axis Ref.)</u>		
<u>RPM</u>	<u>Step Rate</u>	
0	100	AOS $\pm .45^{\circ}$
0	100	LOS $\pm .45^{\circ}$
0	100	AOS - LOS $\pm .9^{\circ}$

The angular width of the sun as seen by the system and the sensor recovery time following saturation by the sun will be measured for the completed system.